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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

1956 SOUTHWESTERN MEETING

AT

THE RICE INSTITUTE, HOUSTON

February 24 and 25, 1956

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BULLETIN

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AMERICAN PHYSICAL SOCIETY

1956 SOUTHWESTERN MEETING AT THE RICE INSTITUTE, HOUSTON, TEXAS, FEBRUARY 24–25, 1956

THE **1956 Southwestern Meeting** of the American Physical Society will be held at Houston, in the buildings of the Rice Institute, on **Friday and Saturday, February 24 and 25, 1956.** This will be our third meeting in Houston: the other two antedated the decision of our Council to hold a meeting annually in the Southwestern area (that of 1955 was our Mexico meeting). Those who have attended the earlier conventions in this ultra-modern city and this distinguished Institute will remember them with pleasure. The evocation of the intimate small meetings of the pre-war era, which these Southwestern meetings have resembled, is growing paler as they follow the upward trend; and the Houston convention is now entering into the phase of four simultaneous sessions, though we have been able to save the opening hour for a single one. The Chairman of the Local Committee, as heretofore, is Professor C. W. Heaps.

Hotels. Rooms have been set aside for our members at the Rice Hotel downtown and the Shamrock-Hilton Hotel uptown. Write to either, mentioning that you are coming to this meeting. From the hotels to the Rice Institute, take bus or taxi. Allow twenty-five minutes for the journey from downtown by bus, fifteen for that from the Shamrock-Hilton.

The **registration desk** will be located in the Physics Laboratory of the Rice Institute. The registration fee of one dollar is to be paid, and entitles you to one copy of this Bulletin for use at the meeting while your subscription copy remains untarnished at home. A bulletin board will be set up near the registration desk. Consult it frequently for notice of messages, of post-deadline papers, and of announcements pertaining to the banquet and other matters.

Among the features which render this meeting outstanding are two that we owe to spatial location and one that results from temporal coincidence. Texas is a great center of geophysical research, and therefore we have two sessions devoted to invited papers in geophysics, G on Friday afternoon (not wholly provided by Texans) and J on Saturday morning. The University of Texas has a Radiobiological Laboratory supported by the United States Air Force, and there is a School of Aviation Medicine at San Antonio: these have supplied us with Session P on Saturday afternoon. A conference of the Committee on Nuclear Cross Sections of the Atomic Energy Commission, convoked to assemble at Houston, was graciously transferred to days adjacent to our meeting; thus we have been able to organize what is very likely the largest Symposium on neutron physics in our history—part of Session A and all of Session E on Friday.

Other invited papers are in the fields of Coulomb excitation, solid-state physics, magnetism, and low-temperature physics.

Eighty-four **ten-minute papers** are distributed among ten sessions, none comprising more than twelve. Here the absences are more surprising than the presences. Reactions of transmutation, molecules, and magnetic resonance account for a larger-than-usual fraction of the total. Cryogenics is almost totally missing, and one can only guess that those who offered descriptions of their work at the recent conference in Baton Rouge thought it equivalent to a meeting of the Society. Semiconductor physics also is almost totally absent, a strange contrast with its abundance in the East.

The **banquet** of the Society will be held on Friday evening in the Rice Hotel. The after-dinner speakers will be announced on a blackboard near the registration desk, if not in this Bulletin. The price will be $3.50. Tickets will be sold at the registration desk up to the last possible moment: we do not know what the last possible moment will be and therefore advise that you buy yours early on Friday morning. Though forms of the type printed on the

inside back-cover page of this Bulletin are seldom used by our members, you will do well to use it on this occasion if you are not sure of arriving early on Friday.

Post-deadline, ten-minute papers pertaining to very recent achievements (attained since the deadline for this meeting) of very special importance will be considered for admission to a special supplementary programme if abstracts thereof are received at the office of the Society not later than Friday, February 17. These abstracts will not be printed. The titles of such as are accepted will be announced on a blackboard near the registration desk, and the papers will be given under the usual ten minute rule at the end of Session K.

If the **Council** of the American Physical Society is convoked to meet at Houston, notice will be sent to its members.

The **preliminary announcement of the 1956 Spring Meeting** at Washington follows hereunder. The calendar of meetings for the remainder of the year 1956 is printed on page 3 of this Bulletin, together with instructions for the preparation of abstracts. At the end of this Bulletin—the second issue published under the new policy and in the new format—are printed the Minutes of the 1955 Chicago meeting, and the texts of three Amendments to the Constitution of the Society which will soon be submitted to balloting by the members of the Society. Errata for the abstracts contained in this issue are to be mailed before the meeting is over to Miss Ruth Bryans, 57 East 55th Street, New York 22, New York. They will be published hereinafter.

KARL K. DARROW, *Secretary*
American Physical Society
Columbia University
New York 27, New York

PRELIMINARY ANNOUNCEMENT OF THE 1956 SPRING MEETING

The **1956 Spring Meeting of the American Physical Society** will be held at Washington, D. C., on Thursday, Friday, and Saturday, **April 26, 27, and 28.** The Sheraton-Park Hotel will function as Central Reservation Bureau, and all requests for rooms should be sent to its Reservation Office for distribution among the Sheraton-Park, Shoreham, and Windsor Park Hotels and the Hotel 2400. We quote from the message of its Sales Manager: "April is a very busy month for all Washington hotels, and it is requested that your members make their reservations early. All hotels concerned would be able to handle more of your members if they would share rooms with other members. This would also enable each member to have a more economical rate." Do not forget to mention this Society when making your reservation!

Deadline is Friday, February seventeenth.

Wanted

The American Physical Society would like to buy the following copies of the 1955 *Physical Review:* January 1, January 15, February 15, and April 1. Payment of $1.50 per copy will be made. Copies should be sent to Mr. Wallace Waterfall, American Institute of Physics, 57 East 55 Street, New York 22, New York.

(Please keep this page on file!)

MEETINGS AND DEADLINES FOR THE REMAINDER OF 1956

Place	*Meeting dates*	*Deadline date*
Houston	February 24–25	past
Pittsburgh	March 15–17	past
Washington	April 26–28	February 17
New Haven	June 21–23	April 27
Eugene*	June 21–23	not decided
Chicago	November 23–24	not decided
Monterey*	December	not decided

* Abstracts for the Eugene and Monterey meetings are to be sent to W. A. NIERENBERG, University of California, Berkeley 4, California, and must reach his office not later than the corresponding deadline date.

Abstracts for the other meetings listed above are to be sent to KARL K. DARROW, American Physical Society, Columbia University, New York 27, New York, and must reach his office not later than the corresponding deadline date. To avoid chance of confusion, please do not send an abstract for any meeting until the deadline date of the previous meeting is at least five days past.

RULES PRESCRIBED FOR ABSTRACTS

The Council has ordered that abstracts shall be not longer than two hundred (200) words or the equivalent thereof. In reckoning equivalence, a footnote is equated to ten words; each line in a table to ten words; a "display" formula—one that requires a line to itself—is an expensive luxury equated to forty words.

Two copies of each abstract must be sent to the appropriate office. They must be typewritten and double-spaced; one must be an original, the other may be an original or a carbon copy. Each abstract must be confined to a single page: if it is too long for a single page it is too long to be printed. Write each abstract as a single paragraph: the suppression of paragraphs costs time and labor to the editors. Do not use very thin paper; a sheet of very thin paper may cause extraordinary trouble when mixed with sheets of reasonable thickness. Look at the abstracts in this *Bulletin* to see how the title of the paper and the name of the author are to be arranged, and follow the example. Issues of the *Bulletin* are sometimes appreciably delayed because the editors have to do what the authors should have done.

Remember the rule of the Council that, if an author submits more than one abstract, all but one must go onto the Supplementary Programme. In enforcing this rule, an abstract is credited to the author whose name appears first in the by-line. **By action of our Council, abstracts will not henceforth be withdrawn from our proofs unless the asker sends ten dollars with his request.**

EPITOME OF THE 1956 HOUSTON MEETING

(Personal names are those of invited speakers.)

Friday Morning

A. Houston, Wimett, Bonner, Taschek. Physics Amphitheatre.

B. General physics. Physics 210.

C. Theoretical physics. Fondren Examination Room.

D. Various topics in nuclear physics. Fondren Lecture Hall.

Friday Afternoon

E. Good, Havens, Newson, Thomas, Harvey. Physics Amphitheatre

F. Solid-state and low-temperature physics. Physics 210.

G. Press, Geyer, Smith, Elsasser. Fondren Lecture Hall.

H. Coulomb excitation; Biedenharn. Fondren Examination Room.

Friday Evening at Seven

Banquet of the American Physical Society; speakers to be announced. Rice Hotel.

Saturday Morning

J. Officer, Howell, Burke, Caldwell. Physics Amphitheatre.

K. Molecules; post-deadline papers, if any. Fondren Examination Room.

L. Magnetic resonance. Physics 210.

M. Reactions of transmutation and nuclear energy-levels, I. Fondren Lecture Hall.

Saturday Afternoon

N. Reactions of transmutation, II; nuclear scattering. Physics 210.

P. Pickering, Sigoloff, Williams. Fondren Lecture Hall.

Q. Reynolds, Selwood, Pake, Bozorth. Physics Amphitheatre.

R. Liquids; optical physics. Fondren Examination Room.

PROGRAMME

FRIDAY MORNING AT 10:00

Physics Amphitheatre

(K. K. DARROW presiding)

Greetings by the President of The Rice Institute

Invited Paper

A1. Some Comments on the Theory of Liquid Helium. W. V. HOUSTON, *Rice Institute.* (30 min.)

Symposium on Neutrons, First Part

A2. Intense Neutron Pulses from a Supercritical Assembly. T. F. WIMETT, *Los Alamos Scientific Laboratory.* (30 min.)

A3. Interaction of High-Energy Neutrons with Nuclei. T. W. BONNER, *Rice Institute.* (30 min.)

A4. Cross Sections and Number of Neutrons in Fast-Neutron Fission. R. F. TASCHEK, *Los Alamos Scientific Laboratory.* (30 min.)

FRIDAY MORNING AT 11:00

Physics Laboratory 210

(W. M. ELSASSER presiding)

General Physics

B1. Core Convection and Shift of the Geographic Poles of the Earth. E. H. VESTINE, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—The major features of the geomagnetic field drift westward at a variable rate with time. From hydromagnetic theory, this predicts a changing angular momentum of the core explaining the irregular rotation of the earth inferred from astronomy, which affects the unit of time.[1] The actual motion of the core inferred from the eccentric dipole motion provides also a changing angular momentum vector transverse to the earth's axis of rotation, which shifts the geographic poles with respect to the axis of rotation of the earth fixed relative to the stars. Checks of this motion are deduced, using charts of geomagnetic secular change since 1900, and world isomagnetic charts since 1700. These show a fair measure of qualitative agreement, but rather poor quantitative agreement, with the results based on the eccentric dipole motion. Possible convection of the mantle would be a more efficient means of shifting the poles, and should be affected by electromagnetic coupling across the core boundary, and by excess heat production within the core.

[1] E. H. Vestine, J. Geophys. Research **58**, 127 (1953).

B2. Study of Recurrent Geomagnetic Activity by Use of Differences. EDWIN J. CHERNOSKY, *Air Force Cambridge Research Center.*—This method of study makes use of mean arithmetic differences of magnetic activity levels instead of the usual correlation coefficients or superposed epoch methods. The international C figures for the years 1935–1944 are the magnetic data employed. Differences between single day values, 3-day and 5-day means, for values or means 27 days apart, are evaluated. In the sunspot cycle the 27-day recurrence tendency is weakest in years of maximum and strongest at minimum for the 3- and 5-day means as well as for the single day values. The maximum to minimum change is greatest for the 3-day means. Overall, the 27-day differences for the 3-day means are about 80% and for the 5-day means about 62% of the differences for the single day values. Differences associated with highly disturbed days ($C=1.7$–2.0) reduce to about 50% at sunspot maximum and to about 40% at sunspot minimum for the 5-day means. For quiet days ($C=0.0$–0.2) the corresponding percentages are 75 and 60. The strongest monthly correlation is found for November and the weakest for March.

B3. Reversals of the Geomagnetic Dipole. WALTER M. ELSASSER, *University of Utah.** On the basis of paleomagnetic data[1] it may now be asserted with a fair degree of certainty that the earth's magnetic dipole has reversed itself an appreciable number of times during the known geological history. The reversals apparently occurred at irregular intervals. Reversals stress the analogy of the geomagnetic dynamo with the corresponding mechanisms in the sun and stars where nearly periodic magnetic reversals are common (sunspot cycle and observed stellar reversals). The dynamo theory permits one to construct hydromagnetic models of reversal, though at present there is ambiguity in the dynamical details. The external features of the reversal process (as it would appear to an observer at the earth's surface) are largely independent of these details, and can be predicted. The mean time of reversal is of the order $4 \cdot 10^3$ years, reliable within better than a factor of two. This is short compared to the mean interval between reversals, in agreement with the observational evidence.

* Supported by the U. S. Office of Naval Research.

[1] S. K. Runcorn, Advances in Phys. (Phil. Mag. Suppl.) **4**, 244 (1955).

B4. Optimum Sample Thickness in X-Ray Measurements.* T. DAVISSON AND H. P. HANSON, *University of Texas.*—An expression for the proper thickness of samples in x-ray absorption edge studies has been given by Sandstrom[1] which is

based on the idea of maximizing the difference in intensity between the two sides of the edge. If one considers a counting method of recording and if the criterion is imposed that the percentage statistical uncertainty in a computed quantity derived from measured intensities is to be a minimum, then optimum thicknesses may be obtained for various x-ray quantities of interest. These include measurements of an absorption coefficient, of edge structure, of jump ratios, and of the absorption due only to a particular electronic shell. Since contrast necessarily is of importance, the results obtained can not differ greatly from Sandstrom's values, but they are enough different to be worth considering in making measurements, particularly on compounds. The effect of the background is to require thinner samples.

* Supported in part by the Robert A. Welch Foundation of Texas.
[1] A. E. Sandstrom, Z. Physik **65**, 632 (1930).

B5. Electron Optical Image Formation Corrected with Respect to Spherical Aberration. WALTER GLASER, *Farrand Optical Company, Inc.*—Using a model field in which the electron trajectories can be rigorously calculated, it is shown that one can obtain a stigmatic virtual image formation by means of two four pole elements turned with respect to each other by 90° for a specific separation of the elements. Combining this stigmatic four pole lens as a projector with a conventional electric or magnetic electron lens as an objective one gets a real enlarged Gaussian image. Placing two electric or magnetic eight pole elements of certain powers, one in the field-free space and one in the plane of the circle of least confusion of the astigmatic bundle in the first four pole element, one can obtain a simple electron optical system, which is corrected with respect to spherical aberration of the third order.

B6. Some Experimental Observations on the Scattering of Microwaves by Ogives and Spheroids. W. C. RHOADS AND M. E. ANDERSON, *North Texas State College.*—Free-space 3-cm wavelength backscattering patterns at 0° elevation and a full 360° azimuth have been obtained for conducting ogives and prolate spheroids of two different sizes ($L=16\lambda$, $L=8\lambda$; $L/d=10$). These data are presented and discussed. Similarities between the near-broadside scattering patterns of the two geometries are pointed out and comparison is made with scattering from cylinders. A trend in the major broadside lobe toward smaller cross section and wider beam width with increasing convexity is indicated; general agreement is noted between experiment and optical theory. Qualitative agreement is found between optical theory and experiment for the nose-on aspect of the spheroids also, even though measurable nose-on signals could only be obtained with the models well into the near-zone of the antenna.

B7. U-Effect. II. An Electrokinetic Phenomenon.*† B. W. FAIN, S. L. BROWN, AND A. E. LOCKENVITZ, *University of Texas.*—When a glass capillary tube filled with a column of alternate layers of mercury and an electrolytic solution is forced to vibrate mechanically, an ac voltage is generated across the ends of the column. A number of aspects of this electrokinetic phenomenon have been investigated both experimentally and theoretically. Semiquantitative data have been obtained for (1) the tube output voltage *versus* amplitude of vibration at fixed frequencies of vibration, (2) the tube output voltage *versus* frequency of vibration (from 20 to 1400 cycles per second) at fixed amplitudes of vibration, and (3) output impedance during vibration for constant unloaded tube output voltage *versus* frequency of vibration. Sufficient data have been obtained so that some generalizations can be made.

* Ueda, Watanabe, Tsuji, and Nishizawa, J. Electrochem. Soc. Japan **20**, 605 (1952) and **21**, 267 (1953).
† E. Yeager and F. Hovorka, J. Acoust. Soc. Am. **25**, 447 (1953).

FRIDAY MORNING AT 11:00

Fondren Library Examination Room

(J. S. LEVINGER presiding)

Theoretical Physics

C1. Integrated Cross Section for the Relativistic Photoeffect. J. S. LEVINGER AND M. L. RUSTGI, *Louisiana State University.**—We have calculated the integrated cross section for a K electron in the Coulomb field of a lead nucleus. We take the cross section for photon absorption from three calculations: (1) for absorption leading to higher discrete levels from Payne and Levinger[1]; (2) for absorption to the continuum from Brown *et al.*[2]; for absorption at high photon energies W, we take $\sigma(W)=\sigma_{PE}-\sigma_{PP}$, as proposed by Brown. Here σ_{PE} is the photoeffect cross section, and σ_{PP} is the cross section for pair production in which the produced electron would have occupied the already occupied K state. Since this $\sigma(W)$ is proportional to W^{-2} at high energies, from the Hall approximation, the integrated cross section converges, giving 87% of the Thomas-Reiche-Kuhn value. By dispersion theory, the forward scattering amplitude of the bound electron is at very high energies 87% of the value e^2/mc^2 for a free electron. We shall also compare the forward scattering amplitude at lower energies with the results of Brown *et al.*

* Supported by the National Science Foundation.
[1] W. B. Payne and J. S. Levinger, Phys. Rev. (to be published).
[2] Brenner, Brown, and Woodward, Proc. Roy. Soc. (London) (A), **227**, 59 (1954), and private communications from G. E. Brown.

C2. Electron Spectrum in Bremsstrahlung. MOTI L. RUSTGI, *Louisiana State University* (introduced by J. S. Levinger).*—Starting with the Born approximation Bethe-Heitler formula for bremsstrahlung,[1] an integration over the photon direction has been carried out. We obtain the differential cross section for production of an electron of energy E making an angle β with the direction of an incident electron of energy E_0. It is possible to carry out the integrations exactly. The final expression has been simplified under the following approximation:

$$\beta^2,\ (\mu/E)^2,\ (\mu/E_0)^2,\ (\mu/k)^2,\ \ll 1 \text{ and } (EE_0/k^2)<1,$$

where $\mu=mc^2$ and k is the photon energy.

* Supported by National Science Foundation.
[1] W. Heitler, *Quantum Theory of Radiation*, third edition, p. 242.

C3. The $d(O^{16},O^{17})p$ Stripping Reaction. E. V. IVASH, *The University of Texas.*—The theory of (d,p), (d,n) stripping reaction taking into account the Coulomb field of the nucleus has been developed by a number of workers.[1] In addition, Tobocman[1] has also considered the effect of the interaction of the outgoing particle with the nucleus. Calculations of the differential cross section based on the Tobocman theory have

been carried out for the $O^{16}(d,p)O^{17}$ reaction for the ground and first excited states for a deuteron energy of 2 Mev, and the results compared with the experimental data of Grosskreutz.[2] In accordance with Tobocman and Kalos[3] the effect of the Coulomb field is to broaden the peaks and fill in the valleys of the differential cross section curve. The effect of nuclear interactions will also be discussed.

[1] W. Tobocman, Phys. Rev. **94**, 1665 (1954); J. Yoccoz, Proc. Phys. Soc. (London), A **67**, 813 (1954); I. P. Grant, Proc. Phys. Soc. (London) A **68**, 244 (1955).
[2] J. C. Grosskreutz, Phys. Rev. (to be published).
[3] W. Tobocman and M. H. Kalos, Phys. Rev. **97**, 132 (1955).

C4. Quantum Mechanics in Real Form. ARTHUR E. RUARK, *University of Alabama.*—Students beginning quantum mechanics often find it hard to get a feeling for the subject, because of the extensive use of complex wave functions and the roundabout tricks used in introducing Hermitian quantities which can be compared with experiment. One remedy is to show that we have to use a pair of coupled Schrödinger equations if we introduce the real and imaginary parts of the wave function. Some mimeographed pages showing key formulas of quantum mechanics, both Newtonian and relativistic, in real form will be available for teachers of the subject. Incidentally, another good measure is to emphasize quite early that mixtures of wave functions are commonly met with, and that resonance phenomena are the basis for the fictions concerning Bohr levels and transitions between them, which still abound in textbooks. This paper is pedagogical. It contains no new physical results.

C5. Quanta as Fusion of Elementary Particles. JOSEPH G. BARREDO,* *Rocasolano Institute C.S.I.C.*—Without the introduction of the magnetic-field hypothesis, the acceleration of particles and their simultaneous recombination was studied. By considering the time derivative of the number of trions, i.e., carriers in front of dipoles,[1] as the characteristic variable of a system of unstable particles, equation $dN/dt=(4qzd/m)^{-\frac{1}{2}}$ $\cdot N^{2}t^{-\frac{1}{2}}$ was deduced which gives the velocity of formation of quanta (by fusion of two particles belonging to a trion) as a function of the mass, m, the charges q and z, of the particles, the length of the dipole, d, the number of trions, N, and the time, t. The value 2 of the exponent was found to be 2 ± 0.001 experimentally, which confirms Yukawa's idea that the de Broglie's conception of the quantum as "fusion" of two particles could survive even if the actual theory of fields must be replaced by a more adequate theory where an elementary particle has its own internal structure. It also confirms Heisenberg's prediction[2a] that de Broglie's conception leads to problems of principle of the same importance as those produced by the discovery of the waves of matter.

* Now at the University of Chicago.
[1] J. G. Barredo, Phys. Rev. **98**, 1530 (1955); **100**, 970 (1955); Naturwiss. (to appear shortly).
[2] (a) W. Heisenberg, Z. Naturforsch. 6a (1951). Article in the monograph *Louis de Broglie* (Albin Michel: Paris, 1952), p. 284. (b) H. Yukawa, *ibid.*, p. 284.

C6. On the Extended Classical Electron. IRVING ZINNES, *University of Oklahoma.*—Since it has never been proved that a nonstatic distribution of charges obeying Maxwell's equations cannot form a self-sustaining stable system, the equations such distributions must satisfy have been developed. The following assumptions were made: (a) the system consists of a continuous distribution of charges and currents, (b) the distribution is periodic in time, (c) the Lorentz force vanishes everywhere. The Fourier space transforms of the charge and current densities satisfy a set of nonlinear integral equations. The solutions have the following properties. (1) At least one solution exists consisting of an arbitrary number of infinitely long straight filaments all parallel to one another. The charge density of each is arbitrary but constant along any one filament; all the charges move in the same direction with the velocity c. (2) If any other solutions exist, there must be either a dc distribution other than that in (1) or a distribution characterized by only one frequency.

FRIDAY MORNING AT 11:00

Fondren Library Lecture Hall

(L. C. BIEDENHARN presiding)

Various Topics in Nuclear Physics

D1. Eighteen-Millisecond As^{75} Isomer.* A. W. SCHARDT, *Los Alamos Scientific Laboratory.*—In order to explain all experimental evidence regarding the excited states of As^{75} Schardt and Welker had to assume that the 305-kev level in As^{75}, is isomeric. This level is populated by a 97-kev transition which occurs in 11% of the Se^{75} electron capture decays. In turn the 305-kev level is depopulated 85% of the time by a cascade of a highly converted 24.4-kev transition and a 280-kev gamma ray, and 15% by the 305-kev ground-state transition. In the present experiment, delayed coincidences between the 97- and 280-kev gamma rays were observed from a Se^{75} source placed at the center of a $2\frac{1}{2}$ by $2\frac{1}{2}$ in. NaI(Tl) well crystal. With this arrangement accidental coincidences are minimized because of high detection efficiency and the fact that most of the gamma rays appear in the "sum" peak at 402 kev. A single channel analyzer, set to cover the 97-kev photopeak, initiated a 10 msec gate which could be delayed in the range from 5μsec to 0.5 sec with respect to the channel pulse. A 100 channel analyzer recorded the scintillation pulses only if they occurred during a gate. In the gated pulse-height spectrum, a 285-kev photopeak is superimposed on the accidental spectrum. A half-life of 18.0 ± 1.5 msec was measured by determining the 285-kev coincidences as a function of gate delay.

* This work performed under the auspices of the U. S. Atomic Energy Commission.

D2. Gamma-Gamma Angular Correlation in Sr^{88}. E. D. KLEMA, *Oak Ridge National Laboratory.*—The directional angular correlation of the 909–1850 kev gamma-gamma cascade in Sr^{88} has been measured with a coincidence scintillation spectrometer using NaI detectors. The spins and parities of the initial and intermediate states of the cascade have been measured as 3^- and 2^+, respectively, in other experiments[1]; hence the present experiment is a sensitive method for determining the purity of the first transition in the cascade. A total of 10^6 coincidence counts were obtained at 19 angular positions with automatic equipment. For a dilute YCl_3 aqueous solution source the observed correlation function, after correcting for the finite angular resolution of the detectors, is given by $W(\theta)=1-(0.0699\pm0.0025)P_2(\cos\theta)$. The theoretical correlation function for the sequence $3(D)2(Q)0$ is $W(\theta)=1-0.07143P_2(\cos\theta)$; thus it is concluded that both of the transitions in the cascade are pure multipoles.

[1] G. R. Bishop and J. P. Perez y Jorba, Phys. Rev. **98**, 89 (1955).

D3. Radiations of Silver-110.* R. F. THOMAS, JR., W. A. WHITAKER, AND C. L. PEACOCK, *Tulane University.*—The radiations accompanying the disintegration of silver-110 have been studied with a flat 180 degree magnetic spectrometer. The beta spectrum is complex and comprises at least three components of allowed shape having end point energies of 0.086 ± 0.005 Mev, 0.536 ± 0.005 Mev, and 2.869 ± 0.020 Mev. The upper limit of 0.1% of all transitions is placed on the intensity of a possible fourth beta group. Observations of internal conversion electrons and photoelectrons from a lead radiator indicate the existence of fourteen gamma rays having energies of 0.116 ± 0.002, 0.447 ± 0.005, 0.575 ± 0.005, 0.620 ± 0.006, 0.656 ± 0.006, 0.685 ± 0.007, 0.705 ± 0.007, 0.759 ± 0.007, 0.820 ± 0.008, 0.883 ± 0.009, 0.945 ± 0.009, 1.382 ± 0.013, 1.492 ± 0.015, and 1.519 ± 0.015 Mev. Beta-gamma coincidence studies with a scintillation spectrometer confirm that there are no gamma rays in coincidence with the 2.869-Mev beta transition.

* Sponsored by the Office of Ordnance Research, U. S. Army.

D4. Further Evidence* for the $_{\Lambda}He^{3}$ Hyperfragment. C. H. SKEEN AND W. Z. OSBORNE, *University of Oklahoma.*—A stack of Ilford G-5 400 micron pellicles has been exposed[1] to the cosmic radiation at about 130 000 ft. A star of the type $(7+3N)$ was found from which emanated a fragment with $Z=2$ or 3. This fragment appeared to come to rest in the emulsion and then decayed into two visible tracks. If one makes the assumption that the fragment came to rest, then it can be explained by the following:

$$_{\Lambda}He^{3} \rightarrow P + D + \pi^{0} + \varphi.$$

The φ value is 34.6 ± 1.6 Mev and the binding energy B_{Λ^0} of the Λ^0 is 3.8 ± 1.6 Mev. Other possible but apparently less likely interpretations will be discussed. Further measurements are still being made.

* For other evidence see W. F. Fry *et al.*, Phys. Rev. **99**, 1561 (1955) and the references listed in this reference.
[1] Flown by courtesy of Major David Simons at Holloman Air Force Base.

D5. Method for Seeking Particles which Ionize More Lightly than the Electron.* HAROLD C. FITZ, JR.,† AND ARTHUR E. RUARK, *University of Alabama.*—The ability of the conventional Wilson chamber to detect fast particles with charge ze less than that of the electron is limited, since specific ionization goes with z^2, speed being held constant. If z were 0.1, a relativistic charged particle would give only one ion pair in 2 cm of ordinary air. Similar remarks apply to hypothetical fast lightly-ionizing magnetic poles. In both cases, background droplets would interfere with detection. Ability to record such particles and to recognize them if they occur can be improved by increasing pressure and by using a chamber of long sensitive time with several photographs per expansion; background droplets not of the same age as the track can then be eliminated from consideration. Leaving aside the effects of raising pressure, we have studied the capabilities of J. A. Bearden's slow-expansion chamber (kindly loaned to us). While Bearden used air and water, we have employed several gases and vapor mixtures, obtaining sensitive times comparable with his. Some are well adapted to the thermal cycle of this chamber. Results will be presented and explained.

* Assisted by a grant from the National Science Foundation.
† Now at Sandia Base.

D6. Formation of Hydrogen Peroxide in Water by 5.3-Mev α Particles. W. H. STOREY, JR., AND R. J. SHALEK, *The Rice Institute and The University of Texas M. D. Anderson Hospital and Tumor Institute.*—The yield of hydrogen peroxide formed in pure water by 5.3 Mev Po^{-210} α particles was determined at rates of energy input of 6.77×10^{15}, 7.56×10^{14}, and 6.48×10^{13} ev/cc sec. The area of the three sources was such that approximately the same total energy was delivered to the water in a given time by the different sources. No dependence of yield on the rate of energy input was demonstrated over the range investigated. An average value, $G=1.17$ molecules $H_2O_2/100$ ev was obtained for irradiations with atmospheric gas conditions. For irradiations with no dissolved gas present, $G=0.81$ molecule $H_2O_2/100$ ev. The activity of the α sources was measured by means of a fixed geometry scintillation method.

FRIDAY AFTERNOON AT 2:00

Physics Amphitheatre

(T. W. BONNER presiding)

Symposium on Neutrons, Second Part

E1. Millimicrosecond Time-of-Flight Neutron Spectroscopy. W. M. GOOD, *Oak Ridge National Laboratory.* (30 min.)

E2. High-Resolution, Slow-Neutron Velocity Spectrometer Used with the 400-Mev Nevis Synchrocyclotron. W. W. HAVENS, JR., *Columbia University.* (30 min.)

E3. Neutron Cross Sections in the Kilovolt Region. H. S. NEWSON, *Duke University.* (30 min.)

E4. Fluctuations of Nuclear Reaction Widths. R. G. THOMAS, *Los Alamos Scientific Laboratory.* (30 min.)

E5. Neutron Resonance Parameters of Uranium-235. J. A. HARVEY, *Oak Ridge National Laboratory.* (30 min.)

FRIDAY AFTERNOON AT 2:00

Physics Laboratory 210

(C. F. SQUIRE presiding)

Solid-State and Low-Temperature Physics

F1. Accelerated Motion of a Dislocation. M. C. GUTZWILLER, *Shell Development Company* (introduced by C. H. Fay).—If some parts of a dislocation loop in an elastic medium undergo an accelerated motion, they radiate acoustic waves. The work of the external stresses is therefore partially lost inside the medium in an irreversible manner. This allows us

to find a lower bound for the external stress which sets the dislocation in motion. It is not necessary to make special assumptions for the center of the dislocation, such as its radius or shape, because the strains and velocities are considered only at large distances from the dislocation. A plane rectangular loop was studied in the case where only one side of the rectangle is moving. The exact expressions for the elastic field are expanded for large distances from the dislocation. The first term describes the radiation of acoustic waves. It is found that the total energy loss is not proportional to the length of the dislocation because of constructive interference between the wavelets which come from the various parts of the dislocation. Moreover, the moving edge dislocation radiates much more energy at high speeds than the screw dislocation. Complete computations were made for a straight infinite, rigidly moving dislocation which is uniformly accelerated with respect to the elastic medium.

F2. Magnetic Properties of Colloidal Nickelous Oxide. JAMES T. RICHARDSON AND W. O. MILLIGAN, *The Rice Institute.*—Magnetic susceptibility measurements at 4°–550°K have been made for iron-free NiO prepared by heat treatment of $Ni(OH)_2$ at 250°–1300°C, the crystal size (electron diffraction methods) varying from 80–2000 A. Large crystals (*ca* 2000 A) exhibit a Néel point at 523°K, the susceptibility, χ, agreeing closely with earlier reports. In colloidal crystals (100–200 A) χ values agree with those for larger crystals above the Néel point, but exhibit maxima at lower temperatures. The temperatures, T_c, at which the maxima appear decrease and the maxima amplitudes increase regularly with decreasing crystal size. Linear plots are obtained for T_c as a function of f, the number of next-nearest magnetic neighbors. Magnetic peaks observed in neutron diffraction patterns both below and above T_c show that the maxima do not correspond to shifted Néel points. Similar susceptibility maxima have been found by others for FeS_x and CrS_x. In view of the linear relationship between T_c and f, it is concluded that the observed magnetic effects are attributable to the small size of the NiO crystals, and the accompanying enhanced specific surface and decreased value of f, which results in an altered magnetic environment. The magnetic susceptibility of nickelous hydroxide follows an ideal Curie-Weiss law from 300° to 90°K. Below 90°K, χ increases more slowly to a value of *ca* 2000×10^{-6} esu at 4°K, and some field dependence is observed, suggesting additional studies for possible ferromagnetism.

F3. Photovoltaic Effect in Molybdenite. C. W. HEAPS AND W. F. LEACH, *The Rice Institute.*—Analysis of samples from various sources, using the thermoelectric method or the photovoltiac effect with a small light spot, shows that impurities may be distributed quite uniformly throughout some specimens, thus producing either *n*-type or *p*-type semiconductors. Other specimens may show complicated distributions of impurities, resulting in numerous barriers throughout the material. A selected barrier gave an emf of 0.8 mv at room temperature when illuminated by a 150-watt lamp at a distance of six feet. The photovoltage increases by a factor of about three when the temperature is lowered from 70°C to −70°C. Preliminary measurements show a sharp drop in photovoltage as the wave length is increased beyond 0.9 micron. The optical activation energy is thus about 1.2 ev. This particular barrier is probably a good representative of $p-n$ junctions in molybdenite.

F4. Effects of Plastic Deformation on Absorption Spectrum and Thermoluminescence of Calcite. D. R. LEWIS, P. K. WEYL, J. W. HANDIN, AND D. V. HIGGS, *Shell Development Company.*—Yule marble and calcite single crystals were deformed dry at room temperature at a constant confining pressure of 2750 bars at a strain rate of 1% per minute. A 17-megaroentgen dose of cobalt-60 gamma radiation prior to deformation reduced the yield stress of the Yule marble somewhat but did not affect the calcite single crystals. Irradiated Yule marble deformed in either compression or extension was colored bright blue; the marble deformed without prior irradiation was colored by gamma irradiation after deformation. Calcite single crystals deformed by translation gliding in uniaxial compression along the *c*-axis turned blue, exhibiting absorption maxima centered about 26 000 cm^{-1} and 17 000 cm^{-1}. No color change occurred in the extension of calcite single crystals along the *c*-axis which takes place by twin gliding. Thermoluminescence glow curves of crystals deformed by translation gliding showed a peak at about 280°C not produced by undeformed irradiated calcite. Deformation by twin gliding increased the ratio of the 240°/305°C peaks.

F5. On the Second-Order Decay of the Thermoluminescence of Polycrystalline Materials. P. K. WEYL, *Shell Development Company.*—The results of an isothermal decay and glow-curve experiment for a thermoluminescent material having second-order kinetics have been investigated. In contrast to the first-order case, the location of the peak of the glow curve depends on the initial trap density. The effect of a distribution of trap densities for a polycrystalline material is investigated. It is found that for a narrow distribution function a plot of the reciprocal of the square root of the light intensity *versus* the time in the isothermal decay experiment will give a straight line whose slope and intercept will depend on the distribution function. The location of the peak of the glow curve is not materially affected by the distribution function, and from its location and the energy of the trap depth a parameter proportional to the initial trap density and independent of the optical efficiency can be determined. Plots of first- and second-order generalized glow curves are presented from which the parameters of an experimental curve can be determined.

F6. Periodic Behavior in the Volatilization of Material from Alloy Surfaces. G. ECKER, *University of Bonn,* Germany.*—It has been shown experimentally that the volatilization of metal from an electrode of an alloy follows a characteristic time sequence during which regular periodic variations occur. By excluding irrelevant phenomena a set of simultaneous differential equations can be derived for the volatilization process which permits the evaluation of the variation of the volatilization process with time. Important parameters are the relative volatilization probabilities of the two components of the alloy, the percentage composition, and the probability of energy dissipation in lower layers of the metal beneath the surface layer. A numerical integration of these equations has been carried out for four examples, to show the influence of various parameters. Curves are derived which correspond to observations, and in particular account for the periodic variations.

* Now at the University of Oklahoma.

F7. Giant Traps. MELVIN LAX, *Bell Telephone Laboratories and Syracuse University.*—The enormous cross sections ($>10^{-13}$ cm^2) observed by Haynes and Hornbeck[1] for electrons in *p*-type silicon can be explained by capture into the hydrogen-like excited states of an attractive center. In view of the Bohr correspondence principle for highly excited states, the motion between collisions is treated classically. The theory extends the Thomson theory for three body recombination of ions in gases. The cross section $\sigma(E_0,U)dU$ is calculated for collisions starting with positive energy E_0 and ending with a binding energy between U and $U+dU$. The total cross section is then written as

$$\sigma(E_0)=\int\sigma(E_0,U)dUP(U),$$

where $P(U)$ is the probability that an electron will stick, i.e., that it will dribble down to the ground state before re-emerging. The probability $P(U)$ of eventual capture is found by solving an integral equation describing the random walk of the electron up and down the energy scale with the boundary condition that once an electron acquires a positive total energy it has escaped. The result of this calculation is insensitive to the details of the trapping potential (other than its long-range Coulomb tail).

[1] J. A. Hornbeck and J. R. Haynes, Phys. Rev. **97**, 311 (1955).
* This abstract was inserted by error in this Bulletin. It will be reprinted in the Pittsburgh Bulletin, and the paper will be given at Pittsburgh.

F8. Oscillatory Hall Effect in Beryllium.* H. W. HEMSTREET AND J. M. REYNOLDS, *Louisiana State University.*—Hall-effect measurements have been made at 1.8°K on beryllium single crystals at three orientations of the principal axis relative to the magnetic field: Be^{-1}, parallel to the field; Be^{-2}, mutually perpendicular to the field and the sample current; Be^{-3}, parallel to the sample current. Instead of calculating the usual constant $R_h = E_x/Hj = V_x t/HI$, a modified one, more characteristic of the Hall effect for metals with strong field dependent resistivities, based on a suggestion by Borvik[1] was used. He suggests the ratio E_x/E_y, where E_x is the Hall field and E_y is the field in the direction of the current. Since in the present study the authors were interested mostly in the relative magnetic field dependence, the "constant" $Q = V_x/V_y H$ was chosen. V_x is the transverse Hall potential and V_y is the IR drop due to the slight misalignment of the Hall probes. For Be^{-1} and Be^{-2} "Q" goes through a maximum value, whereas for Be^{-3} it oscillates in $1/H$. No further analysis has been made. Curves of Q *vs* $1/H$ will be shown.

* Supported by the Office of Ordnance Research and the Research Corporation.
[1] E. S. Borovik, J. Exptl. Theoret. Phys. (U. S. S. R.) **23**, 83 (1952).

F9. Oscillatory Hall Effect in Bismuth at Low Temperatures.* T. E. LEINHARDT AND J. M. REYNOLDS, *Louisiana State University.*—Studies of the dc Hall effect in a nearly cubical, single crystal of bismuth (reported on in an earlier paper)[1] have been extended to fields up to 13.5 kg. Measurements have been made at seven temperatures in the range 1.3°K to 4.2°K and for three different orientations of the crystal. Two sides of this crystal are perpendicular to the trigonal axis. Another pair is perpendicular to the binary. The third pair of sides is parallel to the plane of the trigonal and binary axes. For each orientation of the crystal the field was perpendicular to a pair of sides. By interchanging the Hall and the current probes, it was possible to obtain two sets of data for each field orientation. The single period oscillations occurring with the field parallel to the trigonal axis have been analyzed in terms of the formula describing the de Haas-van Alphen effect with unsatisfactory results. An attempt has been made to determine the components of the complex oscillations found with the field directed along the other axes.

* Supported by the Office of Ordinance Research and the Research Corporation.
[1] Reynolds, Hemstreet, Leinhardt, and Triantos, Phys. Rev. **96**, 1203 (1954).

FRIDAY AFTERNOON AT 2:00

Fondren Library Lecture Hall

(H. T. BYCK presiding)

Invited Papers in Geophysics

G1. Earthquake Waves as a Tool for Exploring Ocean Basins and Continents. FRANK PRESS, *California Institute of Technology.* (30 min.)

G2. The Gravity Anomaly and Its Relation to the Physics of the Earth. R. A. GEYER, *Geophysical Service Inc.* (30 min.)

G3. Application of Generalized Harmonic Analysis to Geophysical Problems. M. K. SMITH, *Geophysical Service Inc.* (30 min.)

G4. Geomagnetic Theory. W. M. ELSASSER, *University of Utah.* (30 min.)

FRIDAY AFTERNOON AT 2:00

Fondren Library Examination Room

(J. C. GROSSKREUTZ presiding)

Coulomb Excitation

H1. (Abstract withdrawn.)

H2. Conversion Spectra of Coulomb-Excited Th^{233} and Au^{197}.† M. S. MOORE, C. M. CLASS, F. W. PROSSER, JR., AND J. P. SCHIFFER, *The Rice Institute.*—The conversion spectra resulting from the electric excitation with protons of Au^{197} and Th^{232} were investigated with a flat-sector shaped pole-face electron spectrometer. Levels in Au were observed at 3.8-Mev bombarding energy corresponding to excitation energies of 191.3, 269.8, 279.5, and 547.7 kev ±0.4%; with K/L ratios of 4.2/1, 6/1, 6.3/1, and 3.6/1, respectively. For the 279-kev line, the $L/M+N$ ratio was found to be 3.1/1. A level in Th was observed at 4.8-Mev bombarding energy at 719-kev excitation, with K/L ratio of 3.5/1. Preliminary value of the

cross section for K-conversion electrons at 90° are 7.9, 1.9, 18.3, and 0.5 μb/steradian for the respective levels in Au, and 1.1 μb/steradian for the level in Th.

† Supported in part by the U. S. Atomic Energy Commission.

H3. Calculation of Electric Dipole Coulomb Excitation.* J. L. McHALE AND R. M. THALER, *Los Alamos Scientific Laboratory* AND L. C. BIEDENHARN, *The Rice Institute.*—Electric dipole excitation, while less common than quadrupole excitation, should exist for heavy elements.[1] The present calculations are useful for the analysis of excitation experiments. The dimensionless excitation function a_0 and the particle parameter a_2, which are related to the total cross section and the γ-correlation function respectively, are calculated in the long wavelength approximation.[2] These functions have been computed over the entire range of $\eta \equiv (Z_1Z_2e^2/\hbar v_{\text{inc}})$, for $\rho \equiv (k_{\text{inc}}/k_{\text{final}}) \leq 2$, corresponding to energy losses of up to 75%. Comparisons between dipole and quadrupole excitation will be made. The evaluation in terms of hypergeometric functions of the integrals

$$I_{l,\,l+1} \equiv \int_0^\infty dr r^{-2} F_l(\eta_1,k_1r) F_{l\pm1}(\eta_2,k_2r),$$

which are required in the calculation will be discussed. It is possible to perform the sum over angular momenta for the excitation function analytically. Two alternate forms of this summation will be presented.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] A. Bohr, On the Theory of Nuclear Fission, Paper U. N. 911, (International Conference on Peaceful Uses of Atomic Energy, Geneva, 1955). This paper presents theoretical evidence for low-lying odd parity levels for heavy elements; for experimental evidence, see Stephens, Asaro, and Perlman, Phys. Rev. **96**, 1568 (1954).

[2] The appropriate formulas are developed by Biedenharn, McHale, and Thaler, Phys. Rev. **100**, 376 (1955).

H4. Calculation of Heavy Particle Bremsstrahlung.* R. M. THALER AND J. L. McHALE, *Los Alamos Scientific Laboratory,* AND L. C. BIEDENHARN, *The Rice Institute.*—Calculations for electric dipole excitation[1] may be applied to the problem of bramsstrahlung resulting from protons and heavier particles. Application of Ehrenfest's theorem connects the integrals required by electric dipole excitation with the integrals required for dipole bremsstrahlung, by the following relation:

$$\int_0^\infty dr r^{-2} F_l(\eta_1,k_1r) F_{l\pm1}(\eta_2,k_2r) = -\left[\frac{\hbar^2(k_2^2-k_1^2)^2}{4MZ_1Z_2e^2}\right]\int_0^\infty dr r F_l(\eta_1,k_1r) F_{l\pm1}(\eta_2,k_2r). \quad (1)$$

The bremsstrahlung formula may, therefore, be written, in terms of the quantities a_0 and a_2, as

$$\frac{d\sigma}{d\Omega} = \frac{8}{3\pi}\left(\frac{Z_1^2Z_2A_2 - Z_2^2Z_1A_1}{A_1+A_2}\right)^2 \times \left(\frac{e^2}{\hbar c}\right)^3 \frac{a_0}{k_1k_2}[1+\tfrac{1}{2}a_2P_2(\cos\theta)]\frac{d\omega}{\omega}. \quad (2)$$

The relation between this quantum-mechanical treatment and the semiclassical theory will be presented.[3] The effect of retardation will be discussed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] McHale, Thaler, and Biedenharn (preceding abstract).

[3] For a similar discussion, see S. Drell and K. Huang, Phys. Rev. **99**, 686 (1955). These authors calculated proton bremsstrahlung according to Sommerfeld's method for 2-Mev protons on tin ($\rho=1.04$, $\eta=5.64$). The present calculation appears to be more suited for calculation over a large range of both incident and gamma-ray energies.

H5. Magnetic ($M1$) and Mixed ($M1$–$E2$) Transitions in Coulomb Excitation.* L. C. BIEDENHARN, *The Rice Institute,* AND J. L. McHALE AND R. M. THALER, *Los Alamos Scientific Laboratory.*—Results have already been given for pure electric quadrupole excitation.[1] In that work the effect of spin was unimportant. For magnetic excitation spin clearly enters in a significant way, so that alpha excitation differs from excitation by protons. For pure magnetic dipole transitions, two separate terms are seen to enter the functions $b_{0,2}(M1)$; *viz.*,

$$b_{0,2}(M1) \sim \left\{ \Sigma l(l+1)(l+2)\left[\int_0^\infty dr r^{-2} F_l(\eta_1,k_1r) F_l(\eta_2,k_2r)\right]^2 + (\text{const})\mu^2 b_{0,2}(E2)\right\},$$

where the $b_{0,2}(E2)$ are given elsewhere.[1] The first term of this expression arises from convection currents alone, the second from spin-spin interactions alone; spin-current terms do not arise for unpolarized incident beams. For alpha-particle excitation the spin-spin term is zero, so that $a_2(M1) \equiv [b_2(M1)/b_0(M1)] = 1$. For mixed ($M1-E2$) excitation, the mixed functions $b_{0,2}(M1-E2)$ must also be calculated. Here again only convection current terms enter for unpolarized incident beams. Since the interference between magnetic and electric excitation cannot contribute to the total cross section, $b_0(M1-E2)=0$. Explicit formulas for $b_2(M1-E2)$ and $b_{0,2}(M1)$ will be presented. Methods for numerical calculation and numerical results will be discussed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] Goldstein, McHale, Thaler, and Biedenharn, Phys. Rev. **100**, 436 (1955); Biedenharn, Goldstein, McHale, and Thaler, Phys. Rev. (to be published).

Invited Paper

H6. Coulomb Excitation of Nuclear Levels. L. C. BIEDENHARN, *Rice Institute.* (30 min.)

FRIDAY EVENING AT 7:00

Rice Hotel

(K. K. DARROW presiding)

Banquet of the American Physical Society

After-dinner speakers to be announced.

SATURDAY MORNING AT 9:30

Physics Amphitheatre

(W. V. HOUSTON presiding)

Symposium in Geophysics

J1. Underwater Sound Transmission and Bottom Reflectivity C. B. OFFICER, *Rice Institute.* (30 min.)

J2. Polar Movement As Indicated by Rock Magnetism. L. G. HOWELL, *Humble Oil and Refining Company.* (30 min.)

J3. Carbon-14 Dating of Geological Sediments. W. H. BURKE, JR., *Magnolia Petroleum Company.* (30 min.)

J4. Gamma Radiation from Inelastic Scattering of 14-Mev Neutrons in the Common Earth Elements. R. L. CALDWELL, *Magnolia Petroleum Company.* (30 min.)

SATURDAY MORNING AT 10:00

Fondren Library Examination Room

(J. R. NIELSEN presiding)

Molecules

K1. Electronic Structure of the Lithium Hydride Molecule. I.* JAMES MILLER, ROBERT H. FRIEDMAN, AND F. A. MATSEN, *The University of Texas.*—A calculation of the total electronic energy of the lithium hydride molecule has been made using a twenty-term wave function consisting of all possible singlet state assignments of the four electrons to the $1s$, $2s$, and $2p\sigma$ orbitals of lithium, and the $1s$ of hydrogen. The elemental integrals were obtained using general programs written for the IBM Card Programmed Calculator, except four which were interpolated from Kotani's tables. Analysis of the wave function and combination of the elemental integrals into matrix elements was accomplished on the IBM Model 650 Computer. The parameters chosen were as follows: orbital exponents: 2.7 for the $1s$ on lithium, 0.65 for the $2s$ and $2p\sigma$ on lithium, and 1.0 for the $1s$ on hydrogen; internuclear distance: 3.02 a.u. The calculated energy, including nuclear repulsion, was 217.04 ev. It was found that the 14 configurations with promoted lithium $1s$ electrons made insignificant contributions as judged by the eigenvectors and the close agreement which was obtained with the results of Ishiguro.[1] Ionic structures contributed some 10%.

* This work was supported by the Office of Ordnance Research, U. S. Army, and the Robert A. Welch Foundation of Houston.

[1] E. Ishiguro, Report on the International Conference on Theoretical Physics at Nikko, Japan, 5 (1954).

K2. Geometry of an Excited State of SO_2 and the Frank-Condon Principle.* M. L. COFFMAN, J. M. CORGAN, C. M. LOYD, AND J. B. COON, *A & M College of Texas.*—The geometry of the excited electronic state associated with the 3700 A absorption system of SO_2 has been determined using the Frank-Condon principle. Some details of the method have been described.[1] From microwave spectra[2] the geometry of the ground state gives $r=1.432$ A, $2\theta=119°\ 32'$. Assuming the angle to be the same in the excited state, normal coordinates Q_i'' and Q_i' are calculated from known frequencies. The relation between Q_i'' and Q_i' involves two parameters C_i which specify the difference in the geometry of the two states. This relation permits evaluation of the Condon overlap integrals in terms of C_i, to the harmonic approximation. Comparison of band intensities measured photographically with the squares of the overlap integrals allows the evaluation of the C_i and hence the excited state geometry. Actually four excited state models are consistant with the observed intensities, but only one of these is consistant with the partially resolved rotational structure of the bands. For the resulting excited state model $r=1.492$ A, $2\theta=124°\ 36'$. This model is consistant with the theoretical qualitative predictions of Mulliken and Walsh.

* Supported by the Office of Scientific Research of the Air Research and Development Command.

[1] J. K. Ward and J. B. Coon, A. F. Technical Note OSR-TN-54-181 (1954).

[2] M. H. Sirvetz, J. Chem. Phys. 19, 938 (1951).

K3. Raman Intensities of the Skeletal Vibrations of Straight Hydrocarbon Chains. O. THEIMER, *University of Oklahoma.*—The normal vibrations of finite, straight, zig-zag chains are calculated from a Urey-Bradley potential using a method which takes into account the boundary effects in finite chains by perturbation methods. The 0.-order solutions are stationary plane waves with wavelength $\lambda=Na/k$, where N is the number of C atoms, $(N-1)a$ is the chain length, k is an integer, odd or even, depending on the symmetry species. The boundary produces mixing of 0.-order solutions but the perturbation terms fall off with $1/N^2$ and are found to be negligible for $N>6$. In case of resonance between different 0.-order solutions mixing is strong but the splitting of frequencies is found of the order of the line width. Thence, 0.-order solutions are used for calculating intensities which are represented, without the use of the bond polarizability approximation, by 4 parameters only. The intensity of the "fundamentals" ($k=1$ or $N-1$) is found proportional to N and 9 times the intensity of the next strongest lines ($k=3$ or $N-3$). The remaining vibrations, including the fundamental vibration perpendicular to the molecular plane are practically inactive. Summarizing, one expects 3 strong chain fundamentals: $\nu_1\simeq 400\times 5/N$ cm^{-1}, $\nu_2\simeq 1000$ cm^{-1}, $\nu_3\simeq 1100$ cm^{-1}. The strong line observed near 890 cm^{-1} cannot be explained as chain vibration.

K4. Vibrational Spectra and Calculated Thermodynamic Properties of Vinyl Chloride and Vinyl Bromide.* C. W. GULLIKSON AND J. RUD NIELSEN, *University of Oklahoma.*—The Raman spectra of CH_2:CHCl and CH_2:CHBr in the

gaseous state have been obtained with a multiple-reflection Raman tube, Toronto-type mercury lamps and a 3-prism glass spectrograph of linear dispersion 15 A/mm at 4358 A. The infrared absorption spectra have been reinvestigated with the aid of a Perkin-Elmer double-pass spectrometer equipped with prisms of LiF, NaCl, and CsBr. The previous assignments of fundamental vibration frequencies have been confirmed or slightly revised, and the spectra have been interpreted in detail. Thermodynamic properties at a number of temperatures have been calculated for the compounds in the gaseous state.

* This work has been supported by the National Science Foundation.

K5. Vibrational Spectra and Calculated Thermodynamic Properties of 1,1-Difluoro-2,2-dibromoethylene.* ROSE THEIMER AND J. RUD NIELSEN, *University of Oklahoma.*—The infrared absorption spectrum of gaseous $CF_2{:}CBr_2$ has been obtained with a Perkin-Elmer double-pass spectrometer equipped with LiF, NaCl, and CsBr prisms and a 1-m cell. The Raman spectrum of the compound in the liquid state has been photographed with a 3-prism glass spectrograph of linear dispersion 15 A/mm at 4358 A. Depolarization ratios have been measured for most of the Raman bands. The 12 fundamental vibration frequencies have been assigned, and the spectra interpreted in detail. Thermodynamic functions have been calculated for the compound in the gaseous state at a number of temperatures above the boiling point.

* This work has been supported by the U. S. Atomic Energy Commission.

K6. Vibrational Spectra of Polyethylenes and Related Substances. J. RUD NIELSEN AND A. H. WOOLLETT, *University of Oklahoma.*—By a special crystal powder technique rather complete Raman spectra have been obtained by polyethylenes of varying crystallinity (Marlex 50, hydrogenated Marlex 50, Marlex 20, and DYNH), Venezuela wax, $n-C_{36}H_{74}$, $n-C_{28}H_{58}$, and stearic acid. New infrared data have been obtained for Marlex 50. The spectral data for highly crystalline polyethylene have been analyzed on the basis of the "line group" given by Tobin[1] and the space group V_h^{16}.[2] The eight Raman-active "line group factor group" fundamentals have been determined, and all but a dozen of the 60 observed infrared bands have been interpreted. The infrared-active methylene wagging and twisting fundamentals in crystalline polyethylene are still uncertain, but values have been assigned for the corresponding frequencies in amorphous polyethylene.

[1] M. Tobin, J. Chem. Phys. **23**, 891 (1955).
[2] C. W. Bunn, Trans. Faraday Soc. **35**, 482 (1939).

K7. Vibrational Spectra of Hexafluorobutadiene-1,3.* J. C. ALBRIGHT AND J. RUD NIELSEN, *University of Oklahoma.*—The infrared absorption spectrum of gaseous $CF_2{:}CF-CF{:}CF_2$ has been obtained with a Perkin-Elmer double-pass spectrometer equipped with prisms of LiF, NaCl, and CsBr. The Raman spectrum of the compound in the liquid state, at 20°C and −120°C, was photographed with a 3-prism spectrograph of linear dispersion 15 A/mm at 4358 A. Polarization ratios were measured for the stronger bands. Weakly exposed Raman spectra were obtained of the compound in the gaseous state at room temperature and in the crystalline state at −160°C. The spectral data are inconsistent with the assumption of the molecular symmetry C_{2h} (*trans*-form), but can be interpreted satisfactorily on the basis of symmetry C_{2v} (*cis*-form). However, the data do not exclude the possibilities that the molecular symmetry is C_2 or that the compound consists of a mixture of molecules of different symmetries. All of the 24 fundamental vibration frequencies have been assigned, and the spectra have been interpreted in detail. Some peculiarities in the spectra and some uncertainties in their interpretation are pointed out.

* This work was done with support of the U. S. Atomic Energy Commission.

K8. Complete π Electron Treatment of the Butadiene Molecule and Ion.* JANICE FAIN AND F. A. MATSEN, *The University of Texas.*—The π electron energy levels of the butadiene molecule have been obtained from a valence bond calculation which included all covalent and ionic structures. The ground-state energy was fouud to be $4W_{2p}-51.166$ ev, 0.17 lower than obtained by Pullman and Baudet[1] from an ASMOCI treatment. The energy of the principal structure, $C-C=C-C$, was found to be $4W_{2p}-49.364$, 0.43 below the self-consistent field calculations of Parr and Mulliken.[2] The ground state of the ion was found to lie at $3W_{2p}-52.633$. To obtain agreement with the experimental ionization energy,[3] 9.0, $-W_{2p}$ must be given the value of 10.5, 0.5 higher than is required for ethylene and the allyl radical.[4]

* This research was supported by Contract DA-23-072-ORD-774 of the Office of Ordnance Research and the Robert A. Welch Foundation of Houston, Texas.
[1] A. Pullman and J. Baudet, Compt. rend. **238**, 241 (1954); A. Pullman, J. chim. phys. **51**, 188 (1954).
[2] R. G. Parr and R. S. Mulliken, J. Chem. Phys. **18**, 1338 (1950).
[3] T. M. Sugden and A. D. Walsh, Trans. Faraday Soc. **41**, 76 (1945).
[4] Lefkovits, Fain, and Matsen, J. Chem. Phys. **23**, 1690 (1955).

K9. Effects of High Pressure on the Near-Ultraviolet Absorption Spectra of Monosubstituted Benzenes. W. W. ROBERTSON, S. E. BABB, JR., AND F. A. MATSEN, *The University of Texas.*—The effect of pressure upon ultraviolet absorption spectra of benzene and certain of the monosubstituted benzenes has been investigated up to 5500 bars. The spectra broaden and shift to longer wavelengths as the pressure is increased. Since the variation of dielectric constant with pressure is known, the effects can be discussed in terms of the former. The wavelength of a particular band varies linearly with dielectric constant and extrapolates to the vapor value for $k=1$. As has been previously suggested on theoretical grounds, the slope of the line is proportional to the oscillator strength.

Post-Deadline Papers, If Any

SATURDAY MORNING AT 10:00

Physics Laboratory 210

(G. E. PAKE presiding)

Magnetic Resonance

L1. Nuclear Magnetic Moment of Cobalt-56. R. C. SAPP,* *Rice Institute,* AND C. M. SCHROEDER,† *Ohio State University.*—The magnetic moment of the ground state of Co^{56} has been determined from measurements of the dependence of the angular distribution of the nuclear gamma rays following positron decay and electron capture on the degree of orienta-

tion of the parent nucleus.[1] Nuclear polarization is produced at low temperatures in an external magnetic field of 200 gauss; the cobalt is incorporated in single crystals of cerium magnesium nitrate. Preliminary results, interpreted with the aid of microwave resonance data[2] on comparable salts, yield a nuclear gyromagnetic ratio of 0.66 ± 0.04, which is in good agreement with the value 0.7 ± 0.2 obtained by Gallaher *et al.*[3] using Bleaney alignment. From current information on the decay scheme of Co^{56} it appears practically certain that the ground-state spin is either 4 or 5; for the latter choice the present results give a corresponding magnetic moment of $3.30 \pm .20$ n.m.

* Welch Foundation Postdoctoral Fellow.
† Frederick Gardner Cottrell Fellow under a grant given by the Research Corporation.
[1] Jastram, Sapp, Schroeder, and Daunt, N. S. F. Conference on Low Temperature Physics and Chemistry (Baton Rouge, 1955).
[2] R. S. Trenam, Proc. Phys. Soc. (London) A66, 118 (1953).
[3] Gallaher, Whittle, Beun, Diddens, Gorter, and Steenland, Physica 21, 117 (1955).

L2. Measurement of the nmr Relaxation Time T_1 in Binary Mixtures.* A. F. Hildebrandt, W. L. Zingery, and M. Eisner, *Texas A. & M. College.*—The longitudinal relaxation time T_1, of the different chemical groups of alcohol-water mixtures has been observed using a flow technique. It is observed that different groups in a fine structure pattern have different T_1, reflecting their different lattice environments. An estimate of the effects of the importance of interactions with neighboring groups in the same and different molecules can be made. The effects of chemical exchange will be discussed.

* Supported in part by the Air Force Office of Scientific Research.

L3. Magnetic Susceptibility of Ethanol-Water Mixtures. John R. Zimmerman, John L. Fitch, and Irving Weinberg, *Magnolia Petroleum Company.*—Measurements of variations in the local magnetic field environment of the methyl group of ethyl alcohol as a function of the relative concentration of the alcohol and water have been obtained by means of nmr studies. A comparison of these results has been made with magnetic susceptibility measurements obtained by torsion balance and inductance apparatus experiments.[1] Significant differences appear in the comparison and are probably due to differences in purity of the ethanol-water mixture. The contribution to the average local field at the methyl group from the molecules outside a Lorentz sphere accounts for the total variation in this local field. In this instance any contribution to local field variations from the molecules inside the Lorentz sphere is negligible. Accuracy of line shift measurements is better than 1 cycle with a Larmor frequency of 40 megacycles.

[1] S. Broersma, J. Chem. Phys. 17, 873–882 (1949).

L4. Concentration Dependence of Chemical Exchange in Water-Ethanol Mixtures. Irving Weinberg, John L. Fitch, and John R. Zimmerman, *Magnolia Petroleum Company.*—Further experimental study of ethanol-water mixtures has been made by means of nuclear magnetic resonance techniques.[1] Special attention has been given to producing "pure" alcohol and water. As observed in earlier work, there is coalescence of the OH and H_2O lines. The position of the coalesced line is determined within an accuracy of 2% on the basis of a 1/1 molecular concentration of alcohol and water. With proper corrections for susceptibility, the coalesced line is found to have the same resonance position as pure water. Hence after coalescence a further increase of water concentration does not cause any appreciable shift in the coalesced line. Without extrapolation the effect of differential hydrogen bonding in free water as compared with low concentration water in alcohol amounts to a chemical shift of 11 cps with a Larmor precession of 40 megacycles. A noticeable instability of data for shifts of the OH and H_2O lines and in local field measurements of the CH_3 group occurs in the immediate vicinity of the 1/1 molar concentration of alcohol and water.

[1] I. Weinberg and J. R. Zimmerman, J. Chem. Phys. 23, 748–749 (1955).

L5. Nuclear Magnetic Relaxation Times of Two-Phase Systems. Frank J. Karal and John R. Zimmerman, *Magnolia Petroleum Company.*—Measurements of T_1 and T_2 for the proton magnetic resonances in two-phase nuclear systems have been made from nuclear free decay and spin echo signals. In addition to relaxation time values, under suitable conditions the relative amounts of nuclei contributing to the two phases may be obtained. In a two-phase system if either T_{1i} and T_{1j} or T_{2i} and T_{2j} can be accurately evaluated, then certain aspects of the two phases are each subject to independent study. Norberg and co-workers[1] have recently measured several distinct T_2's for the protons in solid polyethylene. Some typical experimental results of relaxation time measurements for two-phase liquid systems subjected to a solid lattice interface will be described to show the possible quantitative usefulness of the study of multi-phase systems by nuclear magnetic resonance pulse techniques. Accuracy has been improved over simple graphical analysis by using least square methods in the evaluation of the relaxation data. Programming of the least square data has been done on our Datatron computer.[2]

[1] Lowe, Bowen, and Norberg, Phys. Rev. 100, 1243 (A) (1955).
[2] Manufactured by Electrodata Corporation of Pasadena, California.

L6. Concentration Dependence of Nuclear Spin-Spin Relaxation Times in Ethanol-Water Mixtures.* R. W. Mitchell, W. L. Zingery, and M. Eisner, *Texas A. & M. College.*—The nuclear spin-spin relaxation time T_2 was observed for hydrogen nuclei contained in mixtures of ethanol and water. Measurements were made at fields of 10 gauss with a resolution of 50 microgauss for 30 ml samples. This resolution was sufficient for the study of concentrations ranging from 0.01 to 1.0 mole fractions of ethanol. The relaxation time was obtained by analysis of the decay of the wiggle transients. The results indicate a broad minimum in T_2 occurring at about 0.25 mole fraction of ethanol. This minimum occurs at the same concentration at which other anomalies display peaks. Similar peaks are observed for viscosity, heat of mixing, and ultrasonic absorption at this concentration.

* Supported in part by the Air Force Office of Scientific Research.

L7. Frequency Dependence of Proton Spin Relaxation in Aqueous Solutions of Paramagnetic Ions. A. W. Nolle and L. O. Morgan, *The University of Texas.*—Thermal and phase memory relaxation times, T_1 and T_2, were determined for protons in aqueous solutions of $Cr(H_2O)_6^{+++}$, $Mn(H_2O)_x^{++}$, and $Co(H_2O)_x^{++}$ at 5.50, 7.75, 14.2, and 28.8 Mc/sec using the spin-echo method of Hahn.[1] In each case T_2 was essentially constant, while T_1/T_2 decreased from 3.7 (at 28.8 Mc/sec) to 1.5 (at 5.50 Mc/sec) in solutions of $Cr(H_2O)_6^{+++}$ and from 10 (noted by Zimmerman[2]) to 2 in solutions of $Mn(H_2O)_x^{++}$. Very little change was noted in solutions of $Co(H_2O)_x^{++}$. Variations appear to be related to differences in correlation time for interaction of protons with the paramagnetic ions and may be interpreted in terms of the general formula of Bloembergen, Purcell, and Pound.[3]

[1] E. L. Hahn, Phys. Rev. 80, 580 (1950).
[2] J. R. Zimmerman, J. Chem. Phys. 22, 950 (1954).
[3] Bloembergen, Purcell, and Pound, Phys. Rev. 73, 679 (1948).

L8. Flux-Stabilizing Servo for Current Regulated Electromagnets. Joseph P. Lloyd, *Shell Development Company* (introduced by C. H. Fay).—Certain uses of magnetic fields demand extreme stability for moderate time intervals. For example, high-resolution nuclear magnetic resonance spectroscopy necessitates a stability of a few parts per trillion for

several tens of seconds if quantitative measurements are to be exploited. A magnetic flux-stabilizing servo has been designed, constructed, and superimposed upon a current-regulated electromagnet resulting in the desired stability. The flux-stabilizing servo consists of a sensing coil, highly damped galvanometer, photocell, dc amplifier, driving coil system, and is effective in the frequency range between 0.003 and 20 cps. A second feedback loop from the output of the dc amplifier to the main current control of the magnet current regulator is of much higher gain, but responds effectively only below one cps and greatly increases the effective range of the fast feedback loop.

SATURDAY MORNING AT 9:30

Fondren Library Lecture Hall

(G. C. PHILLIPS presiding)

Reactions of Transmutation and Nuclear Energy Levels, I

Invited Paper

M1. The Mexican Magnetic Spectrograph for Nuclear Studies. FERNANDO ALBA ANDRADE, *Universidad Nacional Autónoma de México.* (20 min.)

Contributed Papers

M2. Zero-Degree Cross Sections for the $D(d,n)He^3$ Reaction between 1.15 and 4.60 Mev and for the $T(p,n)He^3$ Reaction from 8.8 to 11.4 Mev.* LEONA STEWART, GLENN M. FRYE, JR., AND LOUIS ROSEN, *Los Alamos Scientific Laboratory.*—The cross section at 0° has been measured for the $D(d,n)He^3$ reaction, $E_d=1.15$ to 4.60 Mev and for the $T(p,n)He^3$ reaction,[1] $E_p=8.8$ to 11.4 Mev. Ilford C-2 emulsions were used to measure the neutron flux in good geometry. The shape of the spectrum was determined by a range analysis of the proton recoils projected into a rectangular pyramid of half-angle 17°. Corrections were applied for relative humidity, escape probability and emulsion attenuation.[2] The 0° laboratory cross sections for $D(d,n)He^3$ in mb/steradian, as a function of deuteron energy, are as follows: 1.15 Mev, 29.7; 1.55 Mev, 37.0; 1.85 Mev, 44.3; 2.15 Mev, 43.0; 2.45 Mev, 52.8; 3.15 Mev, 55.9; 3.75 Mev, 62.7; 4.15 Mev, 66.3; 4.55 Mev, 63.4; 4.60 Mev, 72.0. The 0° laboratory cross sections for $T(p,n)He^3$ in mb/steradian, as a function of proton energy, are as follows: 8.8 Mev, 18.0; 10.1 Mev, 23.3; 11.4 Mev, 31.3. The estimated error for the $D(d,n)He^3$ values is ±7% and for $T(p,n)He^3$ is ±20%.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] Acknowledgments are due Dr. F. L. Ribe for his contribution to the $T(p,n)$ experiment.

[2] L. Rosen, Nucleonics **11**, No. 7, 32 (1953); **11**, No. 8, 38 (1953).

M3. $T(d,n)He^4$ Reaction.* S. J. BAME, JR., AND J. E. PERRY, JR., *Los Alamos Scientific Laboratory.*— The $T(d,n)He^4$ reaction has been studied from $E_d=0.2$ Mev to 6.25 Mev, using gas targets bombarded with beams from electrostatic generators. Forward angle recoil protons from polyethylene radiators were detected by triple coincidences of two proportional counters and a scintillation counter in series. Angular distributions were observed every quarter Mev deuteron energy up to 2.0 Mev and every half Mev to 5.0 Mev. The 0° cross section was measured from $E_d=0.5$ to 6.25 Mev. The c.m. ratios $\sigma(\theta)/\sigma(0°)$ for $\theta=0°$, 100°, 180° are 1, 1, 1 at $E_d=0.2$ Mev; 1, 0.95, 0.83 at 1.0 Mev; 1, 0.60, 0.63 at 2.5 Mev, and 1, 0.22, 0.44 at 5.0 Mev. In the lab system $\sigma(0°)$ is 26 mb/sterad at $E_d=1.0$ Mev, 16 mb/sterad at 2.25 Mev, 22 mb/sterad at 4.0 Mev, and 28 mb/sterad at 6.25 Mev. σ_T is 667 mb at 0.5 Mev, 269 mb at 1.0 Mev, 108 mb at 2.5 Mev, and continues to decrease to 89 mb at 5.0 Mev. Preliminary probable errors of ±7% are assigned to absolute cross-section values and ±5% to relative angular distributions. These measurements are being extended to higher deuteron energies.

* This work performed under the auspices of the U. S. Atomic Energy Commission.

M4. Angular Distributions of the Ground-State Neutrons from $Be^9(\alpha,n)C^{12}$.† J. R. RISSER, *The Rice Institute.*—Experimental angular distributions of the ground-state neutrons ($Q=5.7$ Mev) from the $Be^9(\alpha,n)C^{12}$ reaction have been obtained in the range of α-particle energy from 2.5 to 5 Mev. Attempts have been made to fit the experimental distributions from assumptions of angular momentum and parity for excited states of the compound nucleus.[1] Although the possibility of direct interaction has been postulated[2] for the $Be^9(\alpha,n)$ reaction, the calculations indicate that compound nucleus theory is adequate to explain the experimental data for the ground-state neutron group up to 5 Mev. The data above 3.5 Mev are consistent with assumptions of a 5/2 even state at about 4 Mev, a broader overlapping 3/2 even state at about 4.4 Mev, and a 7/2 even state above 5 Mev.

† Supported in part by the U. S. Atomic Energy Commission.

[1] J. M. Blatt and L. C. Biedenharn, Revs. Modern Phys. **24**, 258 (1952).

[2] L. Madansky and G. E. Owen, Phys. Rev. **99**, 1608 (1955).

M5. Neutrons from the Nuclear Reaction $Li^7(\alpha,n)B^{10}$.† H. BICHSEL AND T. W. BONNER, *The Rice Institute.*—Neutrons from the bombardment of thin metallic lithium targets with He^+ ions from a Van de Graaff accelerator have been observed with neutron counters at 0° and 90° to the bombarding beam. Neutron thresholds were observed at 4.38 and 5.51 Mev; these thresholds result when B^{10} is left in the ground state and in the first-excited state at 0.72 Mev. The neutron yield shows resonances at 4.74 and 5.15 Mev corresponding to excited states in B^{11} at 11.69 and 11.95 Mev. The half-width of the resonance at 5.15 Mev is 0.24 Mev and the resonance at 4.74 is even wider. The cross section for neutron emission at 0° is 2.5 and 3.4 mb per steradian at 4.74 and 5.15 Mev, respectively. The yield of neutrons at 0° at an energy just above the second threshold is eight times that just above the first threshold, indicating a higher probability of the reaction going to the first-excited state than to the ground state.

† Supported in part by the U. S. Atomic Energy Commission.

M6. Yield of Gamma Radiation and Neutrons from Alpha-Particle Bombardment of B^{10} and B^{11}.† T. W. Bonner, Alfred A. Kraus, Jr., J. B. Marion, and J. P. Schiffer, *The Rice Institute.*—The cross section for the production of neutrons and γ radiation in B^{10} and B^{11} has been measured for 1.9- to 5.3-Mev He^+ ions accelerated by a Van de Graaff generator. Neutron yields have been measured at 0° and 90° and γ rays at 0° and 75°. In the bombardment of B^{11} many sharp resonances were observed for neutron emission at energies in Mev of 2.06 (resonance width $\Gamma=59$ kev), 2.60 ($\Gamma=90$ kev), 2.93 ($\Gamma<3$ kev), 2.97 ($\Gamma\sim7$ kev), 3.23 ($\Gamma=25$ kev), 3.54 ($\Gamma=20$ kev), 3.72 ($\Gamma=40$ kev), 3.92 ($\Gamma=70$ kev), 4.25 ($\Gamma\sim10$ kev), 4.34 ($\Gamma=35$ kev), 5.00 ($\Gamma=72$ kev). Resonances in the emission of neutrons and 3.1 and 3.9 Mev γ radiation from the (α,n) and $(\alpha,p\gamma)$ reactions in B^{10} were observed at energies in Mev of 2.16 ($\Gamma=30$ kev), 2.26 ($\Gamma=110$ kev), 2.90 ($\Gamma=200$ kev), 4.53 ($\Gamma\sim130$ kev), and 5.36 ($\Gamma\sim100$ kev). Resonances from γ radiation only were observed at α-particle energies of 3.5 Mev ($\Gamma\sim500$ kev) and at 3.9 Mev ($\Gamma\sim150$ kev). Gamma radiation for inelastic scattering of α particles leaving B^{10} excited to 0.72 Mev was also observed. The yield of neutrons from both B^{10} and B^{11} is largely due to a nonresonant process at the higher bombarding energies.

† Supported in part by the U. S. Atomic Energy Commission.

M7. Angular Distribution of Gamma Rays from the Reaction $Be^9(\alpha,n\gamma)C^{12}$.† F. W. Prosser, Jr., Alfred A. Kraus, Jr.,* and J. P. Schiffer, *The Rice Institute.*—The excitation function for all neutrons and gamma rays from the reaction Be^9 plus alphas has been measured by Schiffer, Bonner, Kraus, and Marion.[1] The reaction yields neutrons going to the ground state and the first-excited state of C^{12}. The angular distribution of the gamma rays from the first-excited state (4.43 Mev) has been measured. The distributions have no terms of higher power of $\cos\theta$ than four, and no odd powers of $\cos\theta$, as is to be expected from the spin two assignment. The levels in the excitation function are quite broad and in general overlapping. At the higher bombarding energies the barrier penetrabilities allow several l-values to be included. These facts make the analysis ambiguous. Possible spin assignments will be discussed.

† Supported in part by the U. S. Atomic Energy Commission.
* Now at College of the Pacific.
[1] Schiffer, Bonner, Kraus, and Marion, Bull. Am. Phys. Soc. **31**, No. 1, 20 (1956).

M8. The $C^{12}(He^3,n)O^{14}$ Reaction. J. W. Butler, *Naval Research Laboratory.*—The threshold for the $C^{12}(He^3,n)O^{14}$ reaction has been measured using the singly ionized He^3 beam from the NRL 2-Mev Van de Graaff accelerator and a carbon target deposited onto a silver backing. The tentative value for this threshold is 1435 kev in the laboratory system of coordinates and is approximately 40 kev below the calculated position based on a table of mass defects.[1] A search for the $N^{14}(He^3,n)F^{16}$ threshold was fruitless up to a bombarding energy of 2.0 Mev which places a lower limit of 16.1 Mev for the mass defect of F^{16} if it can be formed in this reaction. F^{16} is unstable for proton emission by at least 1.3 Mev.

[1] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **27**, 157 (1955).

M9. (p,n) Reactions on B^{11} and Ni^{64} in the 100-Mev Energy Range. Robert Koch* and Anthony Turkevich, *University of Chicago.*—The (p,n) reaction on B^{11} and Ni^{64} yielding C^{11} and Cu^{64} has been investigated radiochemically in the energy range 80 to 416 Mev. The internal proton beam of the University of Chicago synchrocyclotron was used. Special attention was paid to the energy homogeneity of the bombarding protons, the effect of secondary reactions, and the efficiency of counting of the radiations of the radioactive products. The $Al^{27}(p,3pn)Na^{24}$ reaction was used as a monitor to determine cross sections. The (p,n) reaction cross section drops monotonically from 7.7 and 7.3 mb at the lowest energies to 1.5 and 1.0 mb at the highest energies. The energy dependence is not far from T_0^{-1} for B^{11} and somewhat steeper for Ni^{64}. The (p,n) reaction in the energy range studied should proceed entirely by the "knock-on" process involving an almost head-on collision of the incident proton with a neutron inside the nucleus. The energy dependence observed is close to that calculated on this model using known free neutron-proton scattering cross sections and a Fermi distribution of momenta in the nucleus. The calculated absolute cross sections, however, are smaller than observed.

* Present address: Atomic Power Division, Westinghouse Electric.

M10. Angular Distributions of Two Resolved Neutron Groups from the $B^{11}(d,n)C^{12}$ Reaction.* J. E. Price, C. M. Class, and J. R. Risser, *The Rice Institute.*—Experimental angular distributions of the ground-state neutrons ($Q=13.7$ Mev) and of the neutrons to the first-excited state of C^{12} ($Q=9.3$ Mev) were obtained in the range of deuteron bombarding energy from 1.5 to 5 Mev. The groups were resolved with a proton-recoil counter consisting of a thin polyethylene radiator, scintillation crystal, and a gas proportional counter in coincidence between the radiator and crystal. Above 3.5 Mev the distributions exhibit forward peaks suggestive of stripping with l equal to one. These are accompanied, however, by backward peaks, making the distributions so nearly symmetrical about 90° in the c.m. system that the assumption of broad excited states of the compound nucleus with J equal to 7/2 or more appears adequate to interpret the experimental data.

* Supported in part by the U. S. Atomic Energy Commission.

M11. Excitation Functions and Angular Distributions for the $C^{13}(d,\alpha)B^{11}$ and $C^{13}(d,t)C^{12}$ Reactions.* Jerry B. Marion† and Gustav Weber,‡ *California Institute of Technology.*—Excitation functions for the $C^{13}(d,\alpha)B^{11}$ and $C^{13}(d,t)C^{12}$ reactions have been measured from 1 to 3 Mev at laboratory angles of 45°, 90°, and 135° by observing in the Kellogg Laboratory's 16-in. magnetic spectrometer the momentum profiles from the deuteron bombardment of thin (25 kev), unsupported, 60% C^{13} foils. A number of broad, overlapping resonances were observed for both reactions. In addition, the (d,α) reaction was investigated from $E_d=1.6$ to 2.3 Mev at 8 angles from 72.5° to 140° with a tantalum-backed, 6-kev target, and at forward angles with a thin foil. Two prominent resonances were found at 1.80 Mev ($\Gamma=55\pm10$ kev) and at 2.20 Mev ($\Gamma=22\pm4$ kev). Both of these resonances exhibit strong interference effects with the nonresonant background. The angular distribution of the 2.20-Mev resonance was obtained by separating the observed excitation functions into resonance and nonresonant parts. The resonant portion shows forward and backward peaking. The (d,t) reaction does not show a resonance at 2.20 Mev, but at $\theta=35°$, the α-particle group leaving B^{11} in the first-excited state exhibits a pronounced effect.

* Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
† National Science Foundation Postdoctoral Fellow.
‡ International Cooperation Administration Research Fellow.

M12. Some Reactions Leading to N^{16}.† N. A. Bostrom, E. L. Hudspeth, and I. L. Morgan, *University of Texas.*—Excitation curves for $O^{18}(d,\alpha)N^{16}$ and $N^{15}(d,p)N^{16}$ have been obtained with targets (~40 kev thick) respectively of $BaCO_3$ enriched to 9% in O^{18} and with gaseous targets of normal nitrogen. The preliminary excitation curve for $O^{18}(d,\alpha)$ shows a steep rise from 0.7 Mev to a resonance maximum near 1.25 Mev, with a second resonance at approximately 1.75 Mev. The $N^{15}(d,p)$ curve rises steeply between 1.0 and 1.2 Mev and continues upward with smaller slope to $E_d=2.0$ Mev; some weak resonance structure is indicated. Both curves are being

extended and further work will be done with thinner targets. We attempted also to observe $C^{14}(d,\gamma)N^{16}$, since N^{16} activity is presumed possible from this reaction.[1] We found N^{16} activity, but ascribe all of it within our limits of observation to $O^{18}(d,\alpha)$; this latter reaction was found to be at least 400 times as probable as $C^{14}(d,\gamma)$ at $E_d=1.3$ Mev. The weak activity previously reported[2] from $C^{14}(d,p)C^{15}$ below this deuteron energy is believed to be from bombardment of O^{18}. Proper allowance for this puts these data[2] into agreement with other recently reported results.

† Assisted by the Office of Scientific Research of the U. S. Air Force and by the U. S. Atomic Energy Commission.
[1] H. T. Richards (private communication); Douglas, Broer, and Chiba, Phys. Rev. **100**, 1253(A) (1955).
[2] Rickard, Hudspeth, and Clendenin, Phys. Rev. 96, 1272 (1954).

M13. Inelastic Scattering of Protons from O^{18} and Ni.† R. R. SPENCER, G. C. PHILLIPS, J. P. SCHIFFER, AND T. E. YOUNG, *The Rice Institute.*—Nickel oxide targets, prepared by heating 10-microinch nickel foil in oxygen enriched to 37% O^{18}, were bombarded with protons from the Van de Graaff generator at energies 4.58, 4.94, and 5.28 Mev and the inelastically scattered protons observed using The Rice Institute 180° magnetic spectrometer. For excitation energies to 2.6 Mev one level was observed in O^{18} corresponding to (1.981±0.004)-Mev excitation. This value agrees with that reported from the $O^{17}(d,p)O^{18}$ reaction by Ahnlund and by Holmgren, Hanscome, and Willett. A level in O^{18} reported by Holmgren *et al.*, at about 2.45 Mev of excitation, was not observed. Levels observed in Ni corresponded to energies of excitation: 1.153±0.010, 1.330±0.005, 1.453±0.005, 2.147 ±0.010, 2.275±0.010, and 2.776±0.010 Mev. The 1.330-Mev and 1.453-Mev states are those reported and assigned to Ni^{60} and Ni^{58}, respectively, by Schiffer, Windham, Gossett, and Phillips. The remaining values given were calculated for Ni^{58} although the isotopic assignment is uncertain.

† Supported in part by the U. S. Atomic Energy Commission.

SATURDAY AFTERNOON AT 2:00

Physics Laboratory 210

(J. R. RISSER presiding)

Reactions of Transmutation, II; Nuclear Scattering

N1. Excitation Function for the Reaction $F^{19}(p,\alpha\pi)O^{16}$.* W. A. RANKEN, J. H. MCCRARY, AND T. W. BONNER, *The Rice Institute.*—A magnetic lens pair spectrometer has been used to observe nuclear pairs from the 6.055 Mev level of O^{16}* resulting from the proton bombardment of a 32-kev CaF_2 target. The excitation function for pairs has been obtained for a proton energy range of 3.0 to 4.4 Mev, and will be extended to lower and higher energies. Measurements of gamma ray yields were made at the same time with a scintillation counter. A number of pronounced resonances were observed for pairs at energies in Mev of 3.15 (width $\Gamma\sim0.16$ Mev), 3.36 ($\Gamma=0.09$ Mev), 3.50 ($\Gamma=0.10$ Mev), 3.93 ($\Gamma=0.27$ Mev), 4.33 ($\Gamma=0.10$ Mev). In the energy range 3.0 to 4.4 Mev the excitation curve for pairs is similar to that for gamma radiation.

* Supported in part by the U. S. Atomic Energy Commission.

N2. Energy Levels in Cl^{35} and Cl^{37}.* J. P. SCHIFFER, C. R. GOSSETT, G. C. PHILLIPS, AND T. E. YOUNG, *The Rice Institute.*—The Rice Institute 180° magnetic spectrometer was used in measuring the energies of inelastically scattered protons from targets of normal KI and KCl and NaCl targets enriched in Cl^{35} and Cl^{37}.[1] Bombarding energies of 4.6, 4.7, 4.8, 5.0, and 5.6 Mev were used. One state of 1.713±0.010 Mev was observed in Cl^{37} and two states at 1.220±0.005 and 1.766±0.006 Mev are assigned to Cl^{35} for energies of excitation below 2 Mev. No state below 2.0-Mev excitation was observed in K^{39}, while the first excited state of Na^{22} was determined as 437±5 kev.

* Supported in part by the U. S. Atomic Energy Commission.
[1] Separated isotopes were supplied by the Isotopes Division of the Oak Ridge National Laboratory.

N3. Thresholds in the Reactions $Mn^{55}(p,n)Fe^{55}$ and $Zn(p,n)Ga$.* R. A. CHAPMAN, J. B. MARION,† AND J. C. SLATTERY, *The Rice Institute.*—The reaction $Mn^{55}(p,n)Fe^{55}$ has been investigated in the region of proton energies from 1.7 to 3.9 Mev using a method of detection of thresholds which utilizes two paraffin moderated neutron counters (Counter Ratio Method).[1] Thresholds were observed at proton energies of 1.976±0.005 Mev and 2.385±0.008 Mev corresponding to excited states in Fe^{55} of 0.925±0.006 Mev and 1.327±0.009 Mev using a ground state Q-values of −1.015±0.003 Mev.[2] The reaction $Zn(p,n)Ga$ has been investigated with normal Zn in the region of proton energies from 3.6 to 5.0 Mev. The investigation is now being redone with samples enriched in the isotopes Zn^{67} and Zn^{68} in order to assign the thresholds observed to specific zinc isotopes.

* Supported in part by the U. S. Atomic Energy Commission.
† Now at California Institute of Technology, Pasadena, California.
[1] Brugger, Bonner, and Marion, Phys. Rev. **100**, 84 (1955).
[2] C. H. Johnson (private communication).

N4. Comparison of U^{235} and Pu^{239} Fission Neutron Spectra.* J. A. GRUNDL AND J. R. NEUER, *Los Alamos Scientific Laboratory.*—The relative responses of two groups of threshold detectors were employed in the comparison of the neutron energy spectra from the fission of U^{235} and Pu^{239}. Two small, high resolution fission chambers containing Np^{237} and U^{238}, along with a U^{235} chamber as a monitor of total flux, were placed as close as possible to thin plates of enriched uranium and plutonium which were alternately mounted in the thermal beam of the Los Alamos Water Boiler. After suitable background corrections these detectors indicated a slightly higher energy spectrum for Pu^{239} than for U^{235}. The ratio of the responses for the two fission plates relative to the U^{235} monitor are 1.030±0.012 for the Np^{237} detector, and 1.057±0.014 for the U^{238} detector. In order to compare the high energy spectral tails, the (n,p) threshold reactions in S, Al, and Fe were selected. Foils of these materials were mounted directly onto the fission plates and the resultant beta activities measured. The results indicate an increasing divergence of the spectra at higher energies. A one parameter semiempirical expression $N(E)=1.77\times10^{9}E^{\frac{1}{2}}e^{-BE}$ has been found to fit the U^{235} fission neutron spectrum when $B=0.775$.[1] A value $B=0.746$ for plutonium is consistent with the present data.

* This work supported by the U. S. Atomic Energy Commission.
[1] L. Rosen, Paper 8P-582, International Conference on the Peaceful Uses of Atomic Energy (1955).

N5. Coincident Measurement of the Velocities of Fission Fragments from U^{235}.* W. E. STEIN, *Los Alamos Scientific Laboratory.*—The velocities of the fragment pairs from thermal neutron induced fission of U^{235} have been measured by a time-of-flight method.[1] The masses and energies of the fragments before prompt neutron emission have been calculated with the usual assumptions of an isotropic emission of neutrons from the moving fragments and the conservation of mass and momentum. These data will be compared with the ionization data obtained by Brunton and Hanna,[2] the mass-yield data obtained by radiochemical and mass spectrometric methods,[3] and the calorimetric value of the average total kinetic energy.[4] The mass data from this experiment do not exhibit the fine structure at mass 134 and are in accord with the neutron boil-off hypothesis of Glendenin.[5]

* Work performed under auspices of the U. S. Atomic Energy Commission.
[1] R. B. Leachman, Phys. Rev. **87**, 444 (1952).
[2] D. C. Brunton and G. C. Hanna, Can. J. Research **A28**, 190 (1950).
[3] E. P. Steinberg and L. E. Glendenin, Paper 614 of the International Conference on The Peaceful Uses of Atomic Energy, July, 1955.
[4] R. B. Leachman and W. D. Schafer, Can. J. Phys. **33**, 357 (1955).
[5] L. E. Glendenin, Phys. Rev. **75**, 337 (1949).

N6. Elastic Scattering of Protons by Oxygen in the Energy Region of 2.5 to 5.6 Mev.* R. R. HENRY, G. C. PHILLIPS, C. W. REICH, AND J. L. RUSSELL, *The Rice Institute.*—Using a large volume scattering chamber and protons accelerated by a Van de Graaff accelerator, the yield of protons scattered elastically from gaseous O^{16} was studied in the region of 2.5 to 5.6 Mev. Excitation curves were obtained at angles of 54°44′, 90°, 140°46′, and 166°45′ in the center-of-mass system. In the energy regions where resonances occur data points were taken no farther apart than 3.5 kev. Absolute cross sections were obtained. In addition to resonances previously reported below 4.5 Mev,[1] unreported resonances were observed at 5.16, 5.38, 5.56 Mev of widths about 60, 50, and 60 kev, respectively. No detailed analysis of the data has been completed as yet. However, the excitation curve at 90° in the center of mass confirms that the excited state is F^{17} corresponding to an incident proton energy of 2.66 Mev is a $P_{\frac{1}{2}}$ state.

* Supported in part by the U. S. Atomic Energy Commission.
[1] Laubenstein, Laubenstein, Koester, and Mobley, Phys. Rev. **84**, 12 (1951); Eppling, Cameron, Davis, Divatia, Galonsky, Goldberg, and Hill, Phys. Rev. **91**, 438(A) (1953).

N7. Cross Section for T-He^4 Scattering.* A. HEMMENDINGER, *Los Alamos Scientific Laboratory.*—The T-He^4 differential elastic scattering cross sections were measured for triton energies in the range 1.2–2.2 Mev. At angles less than 40° both scattered and recoil particles were detected simultaneously in the same counter. Chamber entrance and counter windows were thin Pyrex membranes. Preliminary values of center-of-mass cross sections in millibarns per steradian for laboratory triton energy E_T are:

Triton angle Ω	$E_T=1.71$	2.15 Mev
29.8	2310	1248
34.93	1450	905
52.13	463	386
68.97	194	168
85.26	94	82.5
100	56.5	49.3
120	44.0	30.9
140	62.4	29.8
150	101.	40.0
160	194.	...

* This work performed under the auspices of the U. S. Atomic Energy Commission.

N8. Scattering of Alpha Particles from Helium.* J. L. RUSSELL, G. C. PHILLIPS, C. W. REICH, AND R. R. HENRY, *The Rice Institute.*—The alpha-alpha scattering experiment previously reported[1] has been redone with improved charge integration techniques and a more reliable energy calibration at the higher energies. The results are essentially unchanged. Angular distributions were taken at alpha-particle energies of 3, 4, and 5 Mev. Excitation curves were obtained from 3 to 5.5 Mev at c.m. angles of 40° and 54°44′. Absolute geometric cross sections, irrespective of statistics, are of about ±3% accuracy. Revised data and S and D wave phase shifts will be presented. The phase shift information will be compared to those predicted by various effective nuclear potential shapes.

* Supported in part by the U. S. Atomic Energy Commission.
[1] "Scattering of alpha particles from helium and the 3-Mev State in Be^5," Phillips, Russell, and Reich, Bull. Am. Phys. Soc., Sec. M-3, August, 1955 meeting.

N9. Elastic Scattering of Protons from Carbon from 4.0 to 5.5 Mev.* C. W. REICH, G. C. PHILLIPS, J. L. RUSSELL, AND R. R. HENRY, *The Rice Institute.*—Two anomalies have been observed in the elastic scattering of protons from carbon at energies of 4.806 and 5.39 Mev using a differentially pumped methane gas target. The energy of the 4.806 Mev anomaly was established using the annular magnet spectrometer. Excitation curves were obtained at the following center of mass angles: 54°44′, 90°, 125°16′, 131°23′, 137°, 140°46′, and 149°26½′, from 4 to 5 Mev; 54°44′, 90°, 125°16′, and 164°, from 4.8 to 5.6 Mev; and angular distributions at 4.607, 4.958, and 5.569 Mev. The 4.806 and 5.39 Mev anomalies have widths of approximately 15 and 100 kev, respectively, and preliminary analysis indicates that they are due to $5/2^+$ and $3/2^+$ levels in N^{13}. The cross-section data, excepting counting statistics, are believed accurate to ±4%. The assumption of 5 nonzero phase shifts allows a preliminary fit of the data to better than 10% at all angles observed from 4.607 to 4.958 Mev. The 5.39 Mev state gives rise to protons inelastically scattered to the first excited state in C^{13}. Angular distributions of the resultant gamma radiation vary with energy.

* Supported in part by the U. S. Atomic Energy Commission.

N10. Gamma Radiation from the Inelastic Scattering of Fast Neutrons in Carbon.* H. E. HALL AND T. W. BONNER, *Rice Institute.*—Gamma radiation with an energy of 4.43 Mev has been observed with a sodium iodide detector when a graphite ring was bombarded with high-energy neutrons from the $D(d,n)$ nuclear reaction. The intensity of the gamma radiation was measured from threshold to a neutron energy of 8 Mev. Pronounced resonances were observed at neutron energies in Mev of 6.30, 6.49, 7.6, and 7.87. The cross section for the production of 4.43-Mev gamma radiation in carbon at 90 degrees to the beam of neutrons reached a maximum value of 60 mb/sterad at 7.87 Mev. Total cross sections in carbon were also determined above 7 Mev and showed resonances at 7.5 and 7.83 Mev with a maximum cross section at 7.83 of 2.3 barns.

* Supported by the U. S. Atomic Energy Commission.

N11. γ Rays from Inelastic Scattering of Neutrons.* IRA LON MORGAN, *University of Texas.*—A study of the γ-ray yield from the first excited levels in Fe and Al has been made at neutron energies well above threshold. The cross section at 100° for the production of the 0.84-Mev γ ray from Fe, and the 0.87 and 1.01-Mev γ rays from Al, have been determined in the neutron energy region from 3.5 to 4.5 Mev. Some of the variations in cross section are apparently associated with the excitation of higher levels and the resultant cascading through the levels observed; others probably indicate excited levels in the compound nucleus. The γ-ray spectra from the inelastic scattering of 5.0-Mev neutrons from metallic Na and from Cd have been observed. A very prominent 430-kev γ ray and a weaker 2.07-Mev γ ray were detected from Na. The 2.07-Mev level in Na also shows a distinct cascade to the 430-kev level. The spectrum from Cd showed the 2.8- and 0.57-Mev γ rays previously observed at $E_n=3.2$ Mev.[1] All γ rays observed correspond to known levels.

* Assisted by the U. S. Atomic Energy Commission.
[1] Scherrer, Allison, and Faust, Phys. Rev. **96**, 386 (1954).

N12. Effective Capture Cross Sections for the Neutrons in a Critical Sphere of U^{235} Metal.* CLEO C. BYERS, *Los Alamos Scientific Laboratory.*—Capture cross sections for neutrons in a critical sphere of U^{235} metal (the Los Alamos Godiva assembly) have been obtained by a comparison method for a series of odd Z-odd A isotopes ranging from $Z=23$ to $Z=83$. The activity produced in samples irradiated in the center of the Godiva assembly was compared with the activity produced in the same or identical samples when irradiated in the thermal flux of the Los Alamos Water Boiler. Small U^{235} foils were used as primary flux monitors for initial measurements on gold and thereafter gold foils were used to monitor all irradiations. The desired cross sections were then obtained from the ratio of the activities produced, the known thermal cross sections, and the cross sections of the monitor foil for the Godiva neutrons.

* This work supported by the U. S. Atomic Energy Commission.

SATURDAY AFTERNOON AT 2:00

Fondren Library Lecture Hall

(E. L. HUDSPETH presiding)

Symposium in Radiobiology

P1. Effects on Primates of Neutron and Gamma Radiations. J. E. PICKERING, *University of Texas and USAF.* (40 min.)

P2. A Neutron-Insensitive Gamma-Ray Dosimeter. SANFORD SIGOLOFF, *University of Texas and USAF.* (20 min.)

P3. Biological Effects of Microwaves. D. B. WILLIAMS, *School of Aviation Medicine.* (20 min.)

SATURDAY AFTERNOON AT 2:00

Physics Amphitheatre

(N. D. SMITH presiding)

Magnetism and Low Temperatures

Invited Papers

Q1. Magnetic Effects in Transport Phenomena at Low Temperatures. J. M. REYNOLDS, *Louisiana State University.* (30 min.)

Q2. The Mechanism of Chemisorption. P. W. SELWOOD, *Northwestern University.* (30 min.)

Q3. The Overhauser Polarization of Nuclei and Related Effects. G. E. PAKE, *Washington University.* (30 min.)

Q4. Low-Temperature Magnetic Properties of Some Compounds of the Iron Group and Rare-Earth Group Elements. R. M. BOZORTH, *Bell Telephone Laboratories.* (30 min.)

SATURDAY AFTERNOON AT 2:00

Fondren Library Examination Room

(J. G. POTTER presiding)

Liquids; Optical Physics

R1. Ultrasonic Absorption in Tertiary Butanol-Water Mixtures.* R. S. MUSA, *Texas A. & M. College* (introduced by Melvin Eisner).—The coefficient of sound absorption α was studied in binary mixtures of tertiary butyl alcohol and water as a function of concentration. A large peak in absorption at 0.11 mole fraction butanol was observed at low frequencies in agreement with results obtained by other observers. However, α/f^2 was found to be frequency dependent and the peak is greatly reduced at higher frequencies, disappearing at about 70 mc. This type of behavior is usually attributed to the presence of a relaxation mechanism and the data were analyzed from this point of view, making use of several possible models which would account for such a mechanism. A particular model in which the excess absorption is related to the variation of the strength of the hydrogen bonding in the tertiary butanol with aqueous dilution is considered.

* Supported in part by the Office of Ordnance Research.

R2. Propagation of an Impulse Along a Fluid-Solid Interface. Part I. Experimental. W. L. ROEVER AND T. F. VINING, *Shell Development Company* (introduced by N. D. Smith, Jr.).—An attempt is made here to obtain experimentally the complete wave-form response for transient elastic waves in the presence of a boundary. The problem considered is that of a fluid-solid interface excited by a transient pulse emanating from a point source in the fluid. The dilatational and transverse wave velocities in the solid and the dilatational wave velocity in the fluid, which we shall call a, b, and c, respectively, are measured in small samples using conventional pulse methods. For choices of solids where $a>b>c$ and where $a>c>b$ the complete wave forms have been obtained in which the critically refracted dilatational, direct, reflected, and Stoneley waves may be recognized. However, for the case where $a>b>c$ there is a gradual buildup in pressure preceding the time of arrival of a critically refracted transverse wave so that it is difficult to identify as a discrete event on the pressure record. The total response is very close to that obtained in the theoretical development of Part II.

R3. Propagation of an Impulse Along a Fluid-Solid Interface. Part II. Theoretical. E. STRICK, *Shell Development Company* (introduced by N. D. Smith, Jr.).—The theoretical procedure utilized to obtain the close agreement with experiment of the complete pressure wave form as reported in Part I is based upon a method developed by Cagniard.[1] We shall consider the exact solution to the problem of a fluid-solid interface excited by a pressure line source having a delta-function excitation. At large distances the pressure response to a transient point source can be expressed asymptotically in terms of the pressure response of the delta-excited line source leading to the conclusion that both sources will yield similar wave forms. The interpretation of the complete wave form as given in Part I is substantiated. Furthermore, when $a>b>c$ the gradual buildup in response before the expected arrival time t_s for the critically refracted transverse wave front, together with the response in the interval between t_s and the later direct arrival, has many of the properties similar to that of a Rayleigh wave propagating along the free boundary of a semi-infinite elastic solid.

[1] L. Cagniard, *Réflexion et Réfraction des ondes Séismiques Progressives* (Gauthier-Villars, Paris, 1939).

R4. Investigation of the Solitary Wave. J. E. CHAPPELEAR, *Shell Development Company.*—Using a relaxation-iteration procedure the particle velocity components, the profile, and the celerity are calculated for two particular solitary waves. These results are compared with the experimental values of Stephan and Dailey.[1] The agreement is satisfactory, considering the experimental error and the approximation made in the calculations. We also give results for the corresponding oscillatory waves, which are easily obtained from the preceding calculations.

[1] J. W. Dailey and S. C. Stephan, Jr., "The solitary wave," M. I. T. Hydrodynamics Laboratory Technical Report No. 8 (1952).

R5. Character of the Equilibrium of Stratified, Viscous Fluids in Slow Flow Through Uniform Channels. ROBERT L. CHUOKE, *Shell Development Company.*—When one viscous fluid displaces another of different density and viscosity coefficient through a flow channel formed, as an example, by closely spaced parallel plates, the differences in resultant viscous drag can reverse the state of equilibrium relative to that which would hold for the same fluids in an unconfined configuration or in the limit of vanishing viscosity coefficients. For slow flow, the averaged stokes hydrodynamic equations of motion include the effects of viscous drag with a resistive term proportional to the local average velocity. Consequently, the onset of instability is associated with the critical speed W_c normal to the interface, such that for all W, W_c the system is unstable. The criteria and kinematics of instability, in the first order of small perturbations, taking into account buoyancy forces, viscous drag, mean internal friction, and interfacial tension, are described and applied to some experimental observations on a parallel-plate system.

R6. Absorption by Clouds at 8.6-mm Wavelength. ROBERT J. COATES, *Naval Research Laboratory.*—In the summer of 1954 a radio telescope operating at a wavelength of 8.6 millimeters was set up in Oskarshamn, Sweden, for observing the solar eclipse on June 30. During the several weeks before the eclipse the radiation from the sun was measured under a variety of cloud conditions. The observed changes in atmospheric attenuation due to the clouds varied from almost zero to about 3 db depending upon the type of cloud. On the day of the eclipse the changes in optical intensity and radio intensity due to clouds were measured simultaneously. The correlation between these two is discussed.

R7. Limb Darkening of the Sun in Lyman-Alpha Radiation.* S. C. MILLER, JR., *University of Colorado.*—On December 13, 1955, a grating spectrograph with a sun pointer was flown in an intermediate Aerobee rocket at Holloman Air Force Base, New Mexico. Three spectrograms were obtained up to a height of about 130 km. The instrument was designed in part to measure limb darkening of the sun in Lyman-alpha radiation. This was accomplished by choosing a geometry such that the image distance of rays from the sun in a plane parallel to the slit was the same as that of the diffraction pattern of the slit. The intensity of a point on the spectral line therefore corresponded to the average intensity of a thin strip across the sun's disk. Results of limb darkening measurements on the spectrograms will be discussed.

* Research sponsored by Geophysics Research Directorate of the Air Force Cambridge Research Center.

R8. Spectrum of Iodine III.* V. S. THURLOW AND WILLIAM A. RENSE, *University of Colorado.*—The ultraviolet spectrum of iodine was investigated with the view of obtaining term values for the five expected low-lying levels of I III [configuration $(4d)^{10}(5s)^2(5p)^3$]. The source was a vacuum spark discharge between two copper electrodes, one of which was packed with copper iodide. Dispersion was accomplished by a 6000 line/cm concave grating of one meter radius. In the range 200 A to 1500 A wavelengths of 378 lines believed to be due to multiply-ionized iodine were measured. The method used to identify the deep levels of I III was based upon the already established measurements of higher levels. The IBM 701 computer at Los Alamos, New Mexico, was used to determine which of the 378 observed wave numbers tied in with the known higher levels to give consistent transitions to the possible deep levels. Forty-four such lines were found, yielding the expected levels. The levels were tentatively identified as $^3P_1$, 18 981 cm^{-1}; $^3P_1$, 14 680 cm^{-1}; $^3D_{3/2}$, 8594 cm^{-1}; $^3D_1$, 5603 cm^{-1}; and $^4S_1$, 0 cm^{-1}; with latter as the ground state.

* Research sponsored in part by Geophysics Research Directorate of the Air Force Cambridge Research Center.

R9. 2000 A°–4000 A° Hydrogen Continuum in Spark Discharges.* R. G. FOWLER AND W. R. ATKINSON,† *University of Oklahoma.*—Absolute studies have been made of the peak monochromatic emissive power of expansion products from a spark discharge at low pressures in hydrogen. This is found to be of the order of 10^8 watts/cc/cm wavelength at a pressure of 4.5 mm Hg when a 20-μf capacitor charged to 5000 volts is discharged, and the gas is allowed to expand along a linear shock tube a distance of 6 cm to the point of observation.

It is found that the H^- continuum combined with electronic recombination seem to account adequately for the continuum, with a radiation temperature of about 5000K° indicated.

* Supported by the United States Office of Naval Research.
† Now at Phillips Laboratories, Irvington, New York.

R10. Apparatus for Obtaining Optical Absorption Spectra at Pressures to 6000 Bars. D. S. HUGHES AND W. W. ROBERTSON, *The University of Texas.*—A simple and compact pressure system has been designed that makes possible the recording of the optical absorption spectra of solutions at pressures up to 6000 bars. A 20-ton hydraulic ram connected to a hand-operated pump forces a three-quarter inch diameter piston into the high-pressure cylinder. All pressure seals are formed by an O-ring, Teflon, and brass ring assembly. The sample is introduced through a small hole in the side of the cylinder that is sealed by the motion of the piston. A half-inch length of pressure tubing connects the cylinder to the absorption cell. The absorption cell is a high-pressure cylinder having end plugs that support sapphire windows one centimeter thick by one inch in diameter. A one-centimeter diameter beam is transmitted by the cell of optical path length adjustable from zero to three centimeters. High pressures are accurately measured by the use of a manganin resistance gauge. This equipment is being used to study the effects of "inert" diluent molecules upon chromophores.

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Proceedings of the American Physical Society

Minutes of the Meeting Held at Chicago, November 25 and 26, 1955

IN 1955, as nearly though not quite always before, the Autumn or Thanksgiving meeting of the American Physical Society was held in Chicago in the buildings of the University of Chicago. The dates were Thursday, November 25, and Friday, November 26. With 183 contributed papers (168 the previous year) the magnitude of the convention continues its steady upward trend. Not so great in proportion was the rise in the registration. It appears that there were about seven hundred at this meeting. The management of the meeting was in the able hands of Mrs. Dorothy C. Johnson, to whom our debt increases from year to year. The weather was excellent.

The banquet was held on Friday evening in the congenial precincts of the Quadrangle Club. The after-dinner speakers were S. K. Allison, J. W. Buchta, and J. A. Van Allen, who were warmly and deservedly applauded.

The abstracts of this meeting and the titles of the invited papers are reproduced in the November 1, 1955 issue of *The Physical Review*. The lists of those elected to Fellowship and to Membership at the Council meeting held on November 25 are here appended.

Elected to Fellowship: N. Bloembergen, Owen Chamberlain, B. L. Cohen, Ronald Geballe, W. D. Knight, W. B. Kunkel, J. H. Reynolds, M. A. Ruderman, W. W. Scanlon, G. L. Weissler and Alexander Zucker.

Elected to Membership: Hidetaro Abe, Marvin Jack Abrams, *William Thomas Achor, Seymour J. Adler, Frank J. Adrian, *Walter Anthony Albers, Jr., *James S. Albertson, S.J., James Curtice Albright, Frank C. Alexander, Jr., Earl Wayne Allen, *Rufard George Alsmiller, Jr., *Albert Altman, Ernest Ambler, Edward Raymond Andrew, *Joseph Harland Apfel, Cecil Martin Appleberry, Jr., George Thomson Armstrong, Robert Arnal, Renato Ascoli, Leonard V. Azaroff, *Julius Babiskin, *Joseph A. Baicker, *Glenn Charles Bailey, *William Charles Ballowe, Paul Raymond Barker, *Norton Baron, Donatella Baroncini, *Saul David Barshay, *Fred Barson, Giuseppe Franco Bassani, William G. Batt, Charles Sumner Baughman, *Philip Werner Baumeister, *Noemie Benczer, Henry Albert Bent, Wilfried Hellmuth Bergmann, *David Jacob Berkowitz, Peter Michael Bernays, Max Bettman, Donald R. Bianco, Paul W. Bickel, William Reynolds Bitler, *William Antoine Blanpied, *Martin Blume, David Morris Boodman, Raymond Francis Boyle, Robert H. Bragg, *Gilbert Oscar Brink, *Don Edward Brodie, Bernard Brown, *Leon James Bruner, *Dale Brede Bucknam, Mahlon Delaney Bunch, Charles Dodson Buntschuh, Jacob Burde, Eldred L. Burkhard, George Samuel Burkholder, Richard L. Caldwell, Donald Edward Campbell, Frederick Louis Canavan, S.J., Max Edward Caspari, *Theodore Grant Castner, Paul Franklin Chenea, Chien Chou, Robert Edward Chrien, *James E. Cline, Beverly Singer Cohen, C. Daniel Cole, Bernard David Coleman, *Philip Louis Connelly, Eugene N. Cramer, *Paul Joseph Cressman, Albert Victor Crewe, *Ray R. Crittenden, *David Lester Crowther, Cameron Cumming, Stanley Y. Curry, Dominic Anthony Cusano, Richard Timothy Daly, Donald Smith Davis, *Joyce Patricia Davis, Robert E. Davis, *Francis Regis DeFalco, Pierre Gilles deGennes, *Robert Michael Delaney, Gustavo Del Castillo, *John Deryck DePree, Wolfgang Dietz, Violet Marion Diller, *Jack Richard Dixon, Jerome Matthew Dowling, Thomas John Dowling, *William Thomas Duffy, Jr., Richard Henry Duncan, *Lionel David Bureau, *Sanford Elkin, Roger James Elliott, Irving Emin, *Erich Erlbach, Hideo Eto, *Stuart Irwin Fickler, Thomas H. Fields, *Vincent James Folen, George Roy Fox, *Jerrold Franklin, Frederick Strassner Frantz, Jr., *Robert Harold Friedman, Wilfred John Friesen, *Donald Glenn Gardner, James George, *John Maynard Gerhauser, Henry Clay Gibson, Jr., *George Gidal, *Donald Maurice Ginsberg, *George Gioumousis, *David Tobias Goldman, *Rubin Goldstein, *Luiz Carlos Gomes, Subramanian Gopalakrisnan, *Anthony William Gray, *Daniel Mordecai Greenberger, *Malcolm Blake Greenlee, Fred A. Gross, Jr., *Herbert Gursky, *Philip Felix Gustafson, Ira James Gwinn, *Robert Dennis Hall, *Jacque Edgar Hanlon, *Roger James Hanson, Maurice Hardaker, *Jared W. Haslett, Willard DeBarthe Hatch, Imre Joseph Hegyi, *Robert A. Hein, Philip Brian Hemmig, Robert Maurice Hexter, *Roland Wellington Higgs, Isamu Clarence Hisatsune, John Drake Hoffman, Arch Lane Howard, *Webster Eugene Howard, Jr., *Luc Huang, Ralph P. Hudson, Donald Lewis Huffman, John Harvey Huth, Tokuzo Inoue, Yoshio Inuishi, Thomas Henry Jacobi, *Earl Donald Jacobs, *Franz C. Jahoda, *Robert Johannes, Edwin George Joki, Reuben Edwin Joynson, Jr., Allan Clarence Juveland, Thaddeus Kaliszewski, Joseph Anthony Kane, Hilary Andrew Karp, William James Karzas, J. Lawrence Katz, Richard Clifton Keen, William John Keery, Elizabeth Kelly, *Rein Kilkson, Isao Kita, Toshio Kitagaki, *David Kleitman, *Daniel Kleppner, *Edward Alan Knapp, *James Milton Knight, *Fred Stephen Kovacs, Michael Krystichq, John Cornelius Laffan, Jr., Carl Robert Lagergren, Jack Lang, *David Clarence Larson, Don Roderick Lasher, *Frank S. Levin, Harold Ralph Lewis, *John William Lindner, Thomas Edmund Lockary, Stanley Thomas Lonberger, Ward Call Low, *Austin Lowrey, Robert Georges Jary, Eugene Holman Magleby, *Jack Maling, *Stanley Mandelstam, *Peter Mark, Herschel Markovitz, Harvey Marshak, Harold Fletcher Mathis, Wesley George Matthei, Floyd Andrew Mauer, *Marcos Mazari, James Oeland McCaldin, *Charles Simon McCarthy, Jr., *Edward Charles McIrvine, Clifford Charles McMahon, Walter Roy Mellen, John Joseph Meny, Richard Ebert Merrifield, Fritz Walter William Mezger, Harold Chalmers Miller, *James Milton Miller, Lewis E. Miller, *Russell Wayne Mills, *Harihar Misra, Nahonori Miyata, John Kenneth Moore, James H. Moran, Takeo Nagamiya, Andrew A. Nargizian, Richard Ellsworth Nettleton, *Keiichi Nichimura, John Mathias Nilles, Yozo Nogami, *James Sheridan O'Connell, *John Joseph O'Grady, *George Clark Oliphant, Haakon A. Olsen, Haruo Ootuka, *Rosalind Oppenheim, Jesse Orosznik, Joseph Otterman, *Satoshi Ozaki, William John Ozeroff, *Eugene Thayer Patronis, Jr., John Oliver Pehek, Gerald Alvin Peterson, Charles Albert Phillips, Jr., Stanley Joseph Pickart, Miles Thomas Pigott, *Edward A. Piotrowski, *Robert Joseph Potter, *Trilochan Pradhan, Stephen Prager, *John Joseph Quinn, Louis Matthew Rakszawski, John Robert Rees, *Richard Alfred Reiter, *Howard Leonard Resnikoff, *Edward Wells Risley, Jr., *Allan Richard Robinson, *Leonard Oscar Roellig, *Joel Carle Whitehouse Rogers, *William Martin Rogers, *Angelo Rossi, *Sanford Winton Rudman, George Albert Russell, Robert R. Rutherford, *Carl Edward Sagan, *Martin Lee Sage, Claude Joseph Armand St-Arnaud,

ˢBarbara Sakitt, ˢDouglas Howard Sampson, Herbert Joseph Sandberg, Robert Sanders, ˢGeorge Allen Saum, George B. Scheer, Norman Henry Schlemm, Jr., Ernst Schloemann, ˢHerbert William Schnopper, ˢClifford M. Schroeder, Berthold W. Schumacher, ˢArthur August Schupp, Jr., ˢAlan Michael Segar, ˢMichael Lee Seman, ˢShih-Ping Shen, Tsuneto Shimose, Frederick John Shon, James Downs Shreve, Jr., ˢRobert Silver, Richard James Simms, ˢLeland Eugene Sizemore, ˢRichard E. Skinner, Edward Nelson Skomal, Larry Gordon Sloan, ˢGeorge Wolfram Smith, Haldon Littlefield Smith, William A. Smith, Jr., Alexander Somerville, Spencer Willis Spaulding, Mitchell F. Speairs, ˢPeter Spiegler, ˢRichard Spitzer, Howard Parker Stabler, ˢDavid Francis Stafford, Howard Oliver Stearns, Lewis Axtell Stevens, Garth Hill Stonehocker, ˢRobert Joseph Sunderland, Richard Arthur Swalin, Walter H. Tanttila, Takao Tati, ˢLouis Dick Tatro, Kenneth James Teegarden, John William Then, Reuben Thieberger, Richard Frank Thomas, ˢJohn Oliver Thomson, ˢGregory Tice, Lloyd O. Timblin, Jr., Samuel Saul Tobe, Arnold Tubis, George Charles Turrell, ˢAnthony Jack Tuzzolina, Ralph John Tykodi, Salvatore John Vacirca, ˢMilton William Valenta, Richard Fenton Valentine, ˢNed Stuart VanderVen, Joseph Heffley Van Trump, Marcel Vivargent, M. Joan Von Hoene, ˢJerry Donald Wackerlee, ˢWalter Frederick Waldorf, John Linton Walters, John Joseph Wanchow, Jr., ˢThomas Joseph Ward, ˢJohn Lucius Warren, ˢMaurice Barnett Webb, William Ervin Woolf, ˢDonald Lewis Weinberg, ˢGerald Marvin Weinberg, ˢHarold Weitzner, Charles Elmer Weller, John Edward Wertz, ˢWilliam Armstrong Whitaker, ˢJohn Arnold White, ˢGeorge Danley Whitfield, ˢRoger Consaul Wickenden, Howard Morrison Wight, Talmage Theodore Williams, Jr., ˢBenjamin Aloysius Hamilton Winters, ˢEdwin Lewis Woisard, ˢDavid Yue Wong, George N. Woodruff, ˢAlfred Chi-Tai Wu, Fumio Yagi, Yoshio Yamaguchi, James David Yancey, Jr., Shiro Yoshida, Jessie Madison Young, ˢDavid Mandeen Zipoy.

(Superscript s denotes a new member who is receiving the "student concession.")

Proposed Amendments to Constitution of American Physical Society

These amendments are proposed by the Council to the Membership-at-large, and texts thereof will be circulated with ballot forms after the 1956 Annual Meeting.

AMENDMENT ALPHA

Section 1 of Article IV is to be replaced by the following text, and Section 2 is to be renumbered Section 3.

Section 1. For the election of a new Member of the Society, a nomination in due form, signed by two Fellows or Members of the Society, must be sent to the Secretary. The Secretary shall present it at a meeting of the Council, and a favorable vote of the majority of the Councillors present at that meeting (but not fewer than four) shall suffice for election. Alternatively the Council may direct the Secretary or his deputy to circulate to all Councillors a list of all nominations filed in his office at a given time; and it may empower the Secretary or his deputy to admit to Membership any candidate named in that list, against whom no objection shall have been made by any Councillor within a specified time after the distribution of the list; but if within that time objection be made by any Councillor against any candidate named on such a list, the nomination of that candidate must be presented at a meeting of the Council, and a favorable vote of the majority of the Councillors there present shall suffice for election.

Section 2. For the election of a new Fellow of the Society or the transfer or a Member to Fellowship, a nomination in due form, signed by two Fellows or Members of the Society and comprising a list of the principal contributions of the candidate to physics, must be sent to the Secretary. The Secretary shall present it at two meetings of the Council held not less than two weeks apart, and at the second of these meetings (or at a later meeting if circumstances so require) a favorable vote of the majority of the Councillors there present shall suffice for election.

AMENDMENT BETA

Article V shall be augmented by adding the words italicized hereunder:

The officers of the Society shall be a President, a Vice-President, a Secretary, a Treasurer, a Managing Editor, and additional members of a Council and of a Board of Editors as hereinafter provided: *and a Deputy Secretary, a Deputy Treasurer and a Local Secretary for the Pacific Coast, whenever the Council shall have filled these posts by appointment.*

AMENDMENT GAMMA

Article VI. Section 1 shall be augmented by the addition of the words italicized hereunder.

1. The President, Vice-President, Secretary, Treasurer, Managing Editor, the three Past Presidents most recently retired from office, eight other members elected in the manner specified in Article VII, and all Past-Presidents first elected to the office of President before December, 1932, shall constitute a Council which shall have general charge of the affairs of the Society. *The Local Secretary for the Pacific Coast, the Deputy Secretary and the Deputy Treasurer may attend meetings of the Council, but may not vote except that the Deputy Secretary and the Deputy Treasurer may vote in the absence of their respective principals.*

KARL K. DARROW, *Secretary*
American Physical Society
Columbia University
New York 27, New York

The American Physical Society

OFFICERS OF THE SOCIETY FOR 1955

President	R. T. BIRGE	University of California
Vice-President	E. P. WIGNER	Princeton University
Secretary	K. K. DARROW	Bell Telephone Laboratories (Office at Columbia University)
Treasurer	G. B. PEGRAM	Columbia University
Managing Editor	S. A. GOUDSMIT	Brookhaven National Laboratory
Local Secretary for the Pacific Coast	W. A. NIERENBERG	University of California, Berkeley

Past Presidents now on Council: W. F. G. Swann, J. H. Van Vleck, and H. A. Bethe.

Elected Members of the Council: R. B. Brode, W. V. Houston, L. I. Schiff, W. Shockley, John Bardeen, A. O. Nier, F. Seitz, and A. M. Weinberg.

Please cut along this line

(To be sent to Professor C. W. Heaps, Rice Institute, Houston, Texas).

I EXPECT to attend the dinner of the American Physical Society at seven o'clock on Friday evening, February 24. My party will comprise ..... persons.

(*Name*).....

(*Address*).....

(If you want your tickets held to the time of the banquet itself, send a check, made out to American Physical Society, for $3.50 per plate.)